Marine Forces Pacific
Force Warfighting Lab
Expeditionary Bulk Liquids Focus Team

D-Day Mobile Fuel Distribution
Concept Demonstration Report

30-31 October 2000
Exercise Foal Eagle 00
Pohang Korea

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Subj: D-Day Mobile Fuel Distribution Concept Demonstration

Encl: (1) D-Day Mobile Fuel Distribution Concept Demonstration Report

1. This document describes our Force Warfighting Lab D-Day Mobile Fuel Distribution concept demonstration conducted during exercise Foal Eagle 00 in October 2000. It reflects our observations, conclusions, and recommendations regarding fuel distribution technologies and concepts to support the Navy's and Marine Corps' present and emerging operational concepts. It does not necessarily represent the formal position of the Marine Corps or the Department of the Navy.

2. This report is for official use only and may not be released outside the department of Defense without prior approval from the Marine Forces Pacific Force Warfighting Lab.

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Executive Summary

A new concept to distribute fuel from offshore to the beach was demonstrated off the East Coast of South Korea during Exercise Foal Eagle 00. The demonstration was a Marine Forces Pacific (MFP) Force Warfighting Lab (FWL) initiative and supported by the 31st MEU, Task Force 76 and Combined Forces Command (CFC) Korea. This report discusses the demonstration scope, results, and recommendations.

The concept demonstration was titled D-Day Mobile Fuel Distribution (DMFD) and showcased three fuel delivery systems with different sized capacities: 15,000 gallons, 3,000 gallons, and 400 gallons. The technologies that we experimented with in the demonstration were sponsored by the Office of Naval Research (ONR) and developed by the Naval Facilities Engineering Service Center (NFESC). During the demonstration, over 35,000 gallons of JP5 fuel were transported from 25 miles offshore and discharged into a tactical bulk fuel farm on the beach. This was done using the Landing Craft Air Cushion (LCAC) as the delivery platform simulating an Operational Maneuver from the Sea (OMFTS) bulk petroleum distribution operation. This marked the first time that fuel had been transported via LCAC and distributed to a fuel farm on the beach from over-the-horizon.

Demonstration results showed that the 15,000-gallon system was the easiest to use and provided the most payload (fuel delivered per LCAC sortie). However, it is the least flexible, as the fuel cannot be moved forward without pumping it out of the bladders first. The 3,000-gallon system provided a combination of high payload and flexibility. The system was capable of coming straight off the LCAC, loaded aboard a Logistics Vehicle System (LVS) and moved forward to the objective area. The 400-gallon system was the most flexible, however, had the least payload capability and was the most complex to operate.

With the evolving expeditionary maneuver warfare operational concepts, we have to find new ways of distributing fuel to forces ashore. It's through demonstrations like this that we learn what our capabilities and limitations are. This demonstration showed us one way of using advanced technology concepts for fuel distribution. However, our purpose was not to show that we could do it, but rather to discover the flaws in the systems so that it can be fixed before it goes to formal acquisition.

An assessment from the MFP and III Marine Expeditionary Force (MEF) Center for Naval Analysis (CNA) field representatives is provided as Appendix A. The detailed test plan for this demonstration is provided as Appendix B. As background, the report from the preliminary demonstration in Camp Pendleton, California leading up to the final concept demonstration is provided as Appendix C. The expeditionary bulk liquids focus team charter is provided as Appendix D.

Introduction

The capabilities of three expeditionary fuel distribution systems were demonstrated during exercise Foal Eagle 00. The demonstration showcased three systems: a 15,000-gallon system that is offloaded into United States Marine Corps (USMC) fuel assets at the beach support area, a 3,000-gallon system that can be transported forward using the LVS and a 400-gallon modular system that is ground and helicopter transportable. All three systems were transported to the beach from 25 nautical miles offshore using the LCAC.

With the Navy and Marine Corps' dependence on fossil fuels, the ability to provide and distribute bulk fuel to amphibious landing forces during the assault echelon is critical. Previously, the Landing Ship Tanks (LST) class of amphibious ships were used to provide initial bulk fuel sustainment to the landing force until Logistics Over the Shore (LOTS) operations began and matured. However, the Navy has retired all LSTs from the active fleet. Also, the evolving expeditionary maneuver warfare operational concepts present new naval bulk fuel distribution challenges.

To meet this emerging challenge the Marine Forces Pacific Force Warfighting Lab established an Expeditionary Bulk Liquids Focus Team in January 2000. The Bulk Liquids Focus Team consists of bulk petroleum and water experts from MARFORPAC, I MEF and III MEF teaming with Office of Naval Research (ONR) and Naval Facilities Engineering Service Center (NFESC) engineers and scientists. The Team's charter is to explore emerging science and technology for concepts and hardware to meet the Naval bulk petroleum distribution challenge for current and emerging amphibious and expeditionary doctrinal operations.

The Team's first major task was to plan and execute a concept demonstration to simulate fuel distribution concepts to support expeditionary operations. About 35,000 gallons of JP5 fuel was LCAC transported and discharged into a tank farm on the beach from 25 nautical miles offshore. Support from the 31st Marine Expeditionary Unit (MEU) and 3d Force Service Support Group (FSSG) along with the USS FORT McHENRY (LSD-43) and USS ESSEX (LHD-2) was instrumental in making the concept demonstration a great success.

Background

Historically, over 60% of the overall tonnage that U.S. Forces have brought into a contingency theater of operations consist of Class III, bulk petroleum products. For the Navy-Marine Corps team, amphibious bulk petroleum sustainment has transitioned from the World War II mode of 55-gallon drums and 5-gallon fuel cans to amphibious ships with bulk petroleum discharge systems, floating assault fuel lines, tactical fuel systems, and refueling tankers and modules. The modern workhorse for ship-to-shore petroleum support for the Navy was the LST class of amphibious ship. The LST provided the first LOTS sustainment for the landing force via the Navy's Amphibious Assault Bulk Fuel System (AABFS which consists of 10,000 feet of 6–inch diameter floating assault hose line. The AABFS interfaces at the high water mark with the USMC Amphibious Assault Fuel System (AAFS) which consists of 20,000-gallon capacity fabric fuel tanks, assault fuel hoses, and trailer-mounted fuel transfer pumps. This Naval LOTS bulk petroleum distribution system of the LST, AABFS, and AAFS served the Navy and Marine Corps well during the later half of the last century, but things are changing. Due to the emerging doctrine of Operational Maneuver From the Sea (OMFTS) and Ship To Objective Maneuver (STOM), combined with the retirement of the LSTs from the active fleet, the Naval bulk petroleum logistic community must find new hardware, doctrine, and procedures to sustain the warfighter.

D-Day Mobile Fuel Distribution (DMFD) Project

In FY96, ONR initiated the D-Day Mobile Fuel Distribution project. The primary objective was to develop advanced bladder technologies to transport fuel from ships offshore to the beach. As a result of this research, three fuel distribution systems were developed for testing. These three systems are:

15,000-Gallon System

The 15,000-gallon D-Day Mobile Fuel Distribution System (15k DMFD) is designed to maximize the LCAC platform to carry fuel ashore during the initial days of an amphibious operation. The 15k DMFD consists of four 3,750-gallon fabric tanks, resulting in a load of approximately 105,000 pounds for the LCAC. It is envisioned that the 15k DMFD would be deployed during the assault echelon after facilities are in place for transferring bulk fuel at the beach, and at which time one or more LCACs can be designated for fuel transport.

3,000-Gallon System

The 3,000-gallon D-Day Mobile Fuel Distribution System (3k DMFD) is designed to be a mobile system. The 3k DMFD system consists of two collapsible bladders secured to a 1077 flatrack. The assembled and filled system (12 Ton) is readily moved by the LVS MK18A1. Three complete systems and an LVS MK 48/18A1 can be transported by LCAC simultaneously to deliver 9,000 gallons of fuel. The resulting cargo load seen by the LCAC is approximately 60 tons.

400-Gallon System

The EFS 400 is an extension of the D-Day Mobile Fuel Distribution System 400 (DMFD 400). The EFS 400 is a modular system capable of deployment aboard a multitude of ground vehicles and aircraft. The EFS 400 is comprised of individual modules mounted to a unique transport pallet. The individual tank modules break down for reduced storage cube for transport aboard amphibious shipping, yet assemble to provide a Department of Transportation (DOT) certifiable 400-gallon fuel tank. Ten tanks can be mounted on the transport pallet and provide 4,000 gallons of bulk fuel for transport aboard the LVS. All ten tanks can be filled or drained simultaneously through the 4-inch camlock fittings located on the transport pallet, which makes the EFS 400 operate just like any other 4,000-gallon bulk transport container.

400-Gallon System

The modular configuration eliminates fluid slo improve transportation stability much like extensive baffling in larger single tanks. The EFS 400 can be readily configured into a tactical refueler by replacing two tanks with a pumping unit capable of delivering a combined flow of 300 gpm through 4 live reels. The EFS 400 can be further modified by replacing a third tank with a filter/separator unit to provide air-craft quality fuel. Individual tanks can be handled by a 4K forklift, and are transportable by a 5-ton or heavy HMMWV, or as either internal or external cargo aboard the CH-53 and MV-22. Individual tanks can be operated independent of the transport pallet, and can be configured into a stand alone fuel station by using an auxiliary pump assembly (24vDC), which is part of the pump unit.

Previous Testing

All three DMFDS systems have been successfully tested with water in lieu of fuel in previous exercises. During RIMPAC East 2000, the DMFD systems were tested at Camp Pendleton, California (See Appendix C for the test report).

The 400-gallon EFS carried diesel fuel during a Combined Arms Exercise (CAX) at Twentynine Palms, California in June 2000 and also during Millenium Dragon 00.

Exercise Foal Eagle Concept Demonstration

The DMFD concept demonstration during Foal Eagle 00 tested all three of the DMFD systems in an operational environment. For the first time JP-5 was transported versus dyed water simulating fuel. The 15,000-gallon system was operated from the USS ESSEX (LHD-2) while the 3,000-gallon and 400 gallon systems were operated from the USS FORT McHENRY (LSD-43). The DMFD equipment was staged at Marine Expeditionary Camp, Pohang (MEC-P) before being transported to the ships via LCAC and LCU. The individual systems were then assembled and filled with fuel for transport to the beach. The detailed schedule of events for each of the systems is shown in Table 1 (next page).

Table 1. DMFD Test Schedule of Events

DD	Start	Stop	Event
+0	1200	1400	Move DMFD equipment from MEC P to Dogo Beach.

DMFD 15k from USS Essex

DD	Start	Stop	Event
+0	TBD	+ 2hr	Transfer DMFD 15k system to the USS Essex .
+1	0400	0500	Assemble 15k DMFD on LCAC deck.
	0500	0615	Fill 15k system with fuel (approx fill time = 1.25 hrs at 200 gpm).
	0615	0630	LCAC preflight checkout.
	0630	0730	Transport fuel to Dogo Beach (25-mile standoff at 25 knots).
	0730	0800	Offload fuel on beach (time to offload demonstrated during ATD).
	0800	0815	Gripe empty 15k system for return to the USS Essex.
	0815	0830	LCAC preflight check out.
	0830	0930	LCAC return to the USS Essex.
	0930	1045	Refill DMFD 15k (approx. fill time 1.25 hrs at 200 gpm).
	1045	1100	LCAC preflight checkout.
	1100	1200	Transport fuel to Dogo Beach (25-mile stand off at 25 knots).
	1100	1200	Load 15k pallet boxes and ancillary equipment on LCU for transit to Dogo Beach.
	1200	*1430*	LCU transits to Dogo Beach (25-mile stand off at 10 knots).
	1200	1230	Offload fuel on beach (time to offload demonstrated during ATD).
	1230	1530	Pump residual fuel from systems (100 gal/tank) using HERS pump and de-drumming manifold. Fold system and repack into shipping crates.
	1530	1545	LCAC preflight check out.
	1545	1645	LCAC returns to USS Essex, **MISSION COMPLETED.**

DMFD 400 & DMFD 3k from USS Fort McHenry

DD	Start	Stop	Event
+0	TBD	+ 2hr	Transfer DMFD 3k and DMFD 400 to USS Fort McHenry.

DMFD 400

DD	Start	Stop	Event
	TBD	+1.5 hr	Assemble DMFD 400 dispensing configuration, fill with approximately 1,000 gallons (USMC 1391).
	TBD	+.25hr	Load DFMD 400 onto LCAC/LCU for transit to beach.
	TBD		Return DMFD 400 to USS Fort McHenry.
	2000	2030	Assemble 10 400-gallon tanks (USMC 1391).
	2000	*2030*	Install pallet on 1077 flatrack and position in "porta berm".
	2030	2130	Install 10 tanks on pallet and connect to manifold.
	2030	2115	Fill system (filling 6 tanks, 2,280 gallons total at 50 gpm) (dispensing system preassembled).
	2130	2215	Fill system (filling 6 tanks, 2,280 gallons total at 50 gpm

DMFD 3k

DD	Start	Stop	Event
	2000	2045	Assemble 2 systems.
	2215	2315	Fill 2 systems (1,800 gallons per system at 50 gpm = 65 min).
+1	0600	0700	Load onto LCAC using LVS (5 minutes to pick up with LVS, 10 minutes to position on LCAC/unit).
	0700	0800	Gripe four systems.
	0800	0815	LCAC preflight check out.
	0815	0915	Transport fuel to Dogo Beach (25-mile standoff at 25 knots).
	0915	0945	Retrieve first system with LVS and position on beach for offload.
	0945	1000	Offload first system (approx. pump rate 150 gpm).
	0945	1015	Retrieve second system with LVS and position on beach for offload.
	1015	1030	Offload second system (approx. pump rate 150 gpm).
	1015	1030	Retrieve third system and position on beach for offload (retrieval of rear mounted systems goes much faster as LVS operator is working on flat deck rather than ramp).
	1030	1045	Retrieve fourth system and position on beach for offload (retrieval of rear mounted systems goes much faster as LVS operator is working on flat deck rather than ramp).
	1030	1045	Offload third system (approx. pump rate 150 gpm).
	1045	1100	Offload fourth system (approx. pump rate 150 gpm)
	1045	1100	Load first system back onto LCAC.
	1100	1115	Load second system back onto LCAC.
	1115	1130	Load third system back onto LCAC.
	1130	1145	Load fourth system back onto LCAC.
	1145	1230	Gripe 4 4 mobile systems to deck of LCAC.
	1230	1245	LCAC preflight check out.
	1245	1345	Return to the USS Fort McHenry.
	1345	1415	Retrieve first system with LVS and position in "porta berm" for refill.
	1415	1500	Fill first system.
	1415	1445	Retrieve second system with LVS and position in "porta berm".
	1445	1500	Retrieve third system with LVS and position in "porta berm".
	1500	1545	Fill second system.
	1500	1515	Retrieve fourth system with LVS and position in "porta berm".
	1515	1530	Load first system back on LCAC.
	1545	1600	Load second system back on LCAC.
	1545	1630	Fill third system.
	1630	1715	Fill fourth system.
	1630	1645	Load third system back on LCAC.
	1715	1730	Load fourth system back on LCAC.
	1730	1815	Gripe 4 4 mobile systems to deck of LCAC.
	1830	1845	LCAC preflight checkout.
	1845	1945	Transport fuel to Dogo Beach (25-mile standoff at 25 knots).
	1945	2015	Retrieve first system from LCAC.
	2015	2045	Retrieve second system from LCAC.
	2045	2100	Retrieve third system from LCAC.
	2100	2200	Retrieve fourth system from LCAC.
	2200	2215	LCAC preflight check out.
	2215	2315	LCAC return to USS Fort McHenry, **MISSION COMPLETED.**

On the beach, the 15,000-gallon system was de-fueled in place using a USMC 600-gpm portable pump. The fuel was discharged into one of two AAFS 20,000-gallon fabric tanks for later distribution. The 3,000-gallon and 400-gallon systems were offloaded at the beach via USMC LVS Mk48/18A1 self-loading trailers and staged near the AAFS tanks. The systems were de-fueled and then reloaded by the LVS. Although scheduled to make two complete ship-to-shore cycles with fuel, the second run with the 3,000-gallon and 400-gallon systems was made with empty tanks. This was due to overall time constraints and shipboard issues regarding spotting the LCAC to re-fuel both the systems on deck and those offloaded into the well deck. On whole the systems performed well and there were no fuel leaks or spills. The most time consuming event in the system cycle was fueling the tanks using the ship's JP-5 well deck fueling stations. These times and their impact on the overall demonstration are discussed in Appendix A.

Lessons Learned

This demonstration was the FWL's first full-scale Navy/Marine Corps and Combined (CFC/ROKMC) demonstration project. As we digest the year's efforts that culminated during Exercise Foal Eagle 00, there were many lessons learned.

1. The official teaming of the technical and operational community streamlined the communication and greatly facilitated coordination between the warfighter and technology development team. The Team's structure under the MFP FWL allowed the Marines more latitude to participate in the development and testing of emerging concepts and hardware while reducing overhead and external/internal friction.

2. Keeping the Team's membership restricted to only those individuals and organizations that bring value to the initiative was the key. By keeping the Team's membership small (less than 12 members), we were able to focus our energies towards the objectives.

3. The planning and executing phases of the demonstration must have built in flexibility to accommodate changing requirements and schedules.

4. The planning process must start early enough to be included in the exercise planning cycles (normally a year before the exercise schedule date). Though the FWL Executive Steering Committee (ESC) approves the request for the demonstration before planning and coordination commences, the ESC should be kept informed of the events and progress regularly.

5. As CINCPACFLT and its subordinate commands participation was critical for this effort during the planning and execution phases, CINCPACFLT's membership on the Team is essential.

6. Third party documentation of the demonstration is critical to ensure credibility of demonstration assessments and post demonstration reports. For this demonstration, the MFP and III MEF Center for Naval Analysis (CNA) field representatives observed the demonstration and provided final analysis and assessments.

7. Public affairs and protocol support should be resourced early in the planning cycle. We underestimated the scope of VIP and visitor requirements and strained our resources to meet the overwhelming VIP response from both the United States and Republic of Korea.

Recommendations

The demonstration details and results from this demonstration will continue to be discussed and debated by the focus team over the next several months. However, based on observations and the CNA field representatives analysis, there are several preliminary recommendations that we are prepared to make.

1. The 15,000-gallon system is the most mature and almost ready to be handed off to the acquisition community for 6.4 engineering development. This is strictly a Navy system and we recommend that N75 continue its process of procuring the system in FY 05 and FY 06.

2. There are several issues regarding concept of operations that should be considered before final fielding to the operational forces. One such issue is the process of filling the bladders for transportation to the beach. We recommendthat the Team explore the possibility of filling the bladders from alongside L-Class vessels or other ships of opportunity. Once a concept is developed, we recommend that a demonstration/experiment be conducted to test such concepts.

3. The 3,000-gallon system is the most versatile and attractive for the Marine Corps as it combines the advantages of being mobile while requiring minimal storage footprint and offering a high fuel capacity to tare weight ratio. However, the system as presently configured is not ready for fielding as there are technical challenges still to be overcome, such as fuel capacity, baffling, and dispensing. We recommend that the Team continue development of the 3,000-gallon system to address all the technical challenges discovered during this demonstration.

4. The 400-gallon system was the most flexibile in terms of capability offered, but had the largest stowed footprint and was more complex to operate. It is recommended that the focus team consider existing and emerging fuel handling and distribution concepts. An evaluation of the pros and cons of a modular system against it's overall value to the bulk fuel community should be conducted

5. We recommend that the Team provide a listing of all available helicopter and HMMWV transportable bladder technologies in industry and currently under development. From this list, we recommend that the Team provide benefit analysis in regards to suitability for the Marine Corps as it relates to emerging expeditionary maneuver warfare operations.

Conclusions

The concept demonstrations showed, for the first time, that we can transport large quantities of fuel from over-the-horizon to inland objective areas. The demonstrations were an overall success for several reasons:

1. We showed that this technology can and will support the Navy's and Marine Corps' emerging expeditionary warfare operations. Though we encountered difficult challenges throughout the

demonstration, the systems provided enough flexibility to allow the technical and support teams to successfully address the challenges. We met our major objectives without encountering any significant operational or environmental problems.

2. We showed that a strong partnership between the technical and operational community could accomplish great things. By leveraging off each other's strength, we were able to efficiently and effectively accomplish our objectives with the limited resources available.

3. We learned about our capabilities and limitations. Based on what we learned in this demonstration, we can better articulate our requirements and provide meaningful recommendations for the technologies experimented with as well as provide recommendations for other related programs.❖

(CNA Assessment Report) Appendix A

D-Day Mobile Fuel Distribution (DMFD) System Demonstration

Foal Eagle 00

Limited Assessment

November 2000

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Summary

The MARFORPAC Force Warfighting Lab Expeditionary Bulk Liquids Focus Team requested that CNA assess three concept-demonstrator fuel distribution systems during Exercise *Foal Eagle 00*. The three "D-Day Mobile Fuel Distribution" (DMFD) systems would be employed from ships between the time that Marine amphibious forces move ashore and the time that a more robust fuel sustainment system is established (if needed). One is a ship-to-shore system, and the other two support emerging operational concepts such as ship-to-objective maneuver (STOM).

The 15k system carries 15,000 gallons of fuel in four bladders mounted on an LCAC between ships at sea and expeditionary fuel storage facilities on the beach. The 3k system also uses bladders; it holds 1,800 gallons of product, and is mounted to a 1077 flatrack for transport by LVS. The 400 DMFD is a series of 400-gallon tanks mounted to a custom LVS pallet/manifold. Individual tanks may be removed for transport by air, 5-ton, or heavy HMMWV. A total of ten tanks may be mounted on each pallet for 4,000 gallons of product.

Approach

We first laid out the different steps and times involved in deploying and employing each system as recorded during the demonstration. This enabled us to identify routines whose intervals might be shortened through one or more hardware or procedural change, such as shipboard pumping rates. With these data we estimated the resources required to deliver 100,000 gallons of fuel per day inland under different employment concepts and by changing certain variables. The 100,000 gallons is an estimate of the daily consumption of a MEB-sized force less aviation assets. In the first scenario, the two smaller DMFD systems are cycled from ship to objective aboard LCAC/LVS. In the second, the larger 15k system is cycled between the ship and beach, building up fuel which is then shuttled to objectives using the smaller mobile systems aboard LVS. We vary pumping rates in both scenarios.

Findings

For a given fuel capacity, the rate at which fuel may be delivered to inland objectives will be determined primarily by ashore and afloat pumping rates and LCAC availability. Factors such as weather and LCAC loading/unloading times may vary,but they can't be predicted or won't change appreciably.

The following table summarizes the LCAC and fuel distribution system resources required for each scenario with the highest pumping rates. In the first scenario, slightly more than two LCAC and nine 400 DMFD would be needed to meet the 100,000-gallon daily requirement for fuel at objectives. Another LCAC and four more 3k DMFD systems (13 in total) would be needed to meet the same fuel requirement. *The demand for these resources drops by nearly 50 percent in the second scenario, when we use the larger 15k DMFD in combination with the two smaller DMFD systems.*

Scenario (resources req to 100k gal)	3k DMFD	400 DMFD	15k DMFD
(1) Ship-to-objective w/ 3k and 400 DMFD			N/a
LCAC required	3.3	2.3	
DMFD required	13	9	
(2) Combination 15k and 3k/400 DMFD			
LCAC required			1.22
DMFD required	6	5	1.22

Other factors should be considered. These include the ratios of cube and weight to fuel capacity. All things equal, preference might be given to systems that weigh less and have smaller stowed footprints for a set volume of fuel. The 400 DMFD carries the least fuel for its weight and amount of stowage space consumed. It is also the most complex, and a variety of engineering issues need to be sorted out to improve reliability.

Conclusions

Data collected during the *Foal Eagle 00* demonstration suggest that three DMFD systems could meet the Marine Corps' amphibious-assault fuel-distribution requirements individually or in combination. The real issue is, At what cost? The 15k DMFD is easy to assemble and operate, has a small stowed footprint, and provides the largest volume of fuel for its weight.

The 3k and 400 DMFD support STOM concepts, but certain characteristics limit their utility. The 400 DMFD, for example, is too heavy to be transported off-road with all ten tanks fully fueled. It is also more complex than the other systems. More analysis is needed on the virtues of its modularity and suitability for air delivery given its weight-to-capacity ratio.

The existing 3k system is compact and simple, but carries far less fuel than the other two systems. A hybrid system, combining larger baffled bladders with a pump and filter/separator unit, may be desirable. The baffles (and retaining devices) may minimize fluid sloshing and allow for transport when not completely filled. Initial impressions indicate that the system would take up less storage space, would be easier to operate, and could transport more fuel in an off-road mode than the 400 DMFD unit. One trade-off would be modularity.

Much of our analysis of event times hinges on fueling and defueling rates. These are driven by the size of pumps afloat and ashore. Further discussions with the Navy are needed to determine the feasibility of placing larger pumps aboard amphibious ships and/or storing JP-5 in DFM tanks, which are serviced by larger pumps.

Introduction

This paper presents analysis of three fuel distribution systems that were demonstrated during Exercise *Foal Eagle 00*. The demonstration was conducted 30-31 October 2000 in the vicinity of Pohang, Korea. At the request of the MARFORPAC Force Warfighting Lab, two Center for Naval Analyses (CNA) analysts traveled to Korea to observe and collect data on the demonstration. More formally, we were to assess the strengths and weaknesses of each system from deployment through employment. The results of that effort, summarized in this document, might influence the Marine Corps' decision to pursue one or more of the systems. This work draws on and complements more comprehensive analysis being conducted by CNA on OMFTS Class III requirements.[1]

Background

Class III bulk petroleum products account for much of the overall tonnage brought to the theater of operations during past contingencies. Fuel typically was delivered to shore from Landing Ship Tanks (LSTs) via hose to a 20,000-gallon capacity fabric fuel tank at the high water mark. However, all of the Navy's LSTs were retired from active service in the 1990s. This reality coupled with the emerging concepts of Operational Maneuver From The Sea (OMFTS) and Ship-To-Objective Maneuver (STOM) point to the need for new ways of delivering fuel to amphibious forces ashore.

To meet this challenge, MARFORPAC's Force Warfighting Lab established an Expeditionary Bulk Liquids Focus Team in January 2000. The team consists of bulk petroleum and water experts from MARFORPAC, I MEF, and III MEF, as well as engineers from the Naval Facilities Engineering Service Center (NFESC). The team's charter is to experiment with emerging technology concepts to meet existing and future bulk petroleum distribution needs.

The team's first project is the "D-Day Mobile Fuel Distribution" (DMFD) system initiative. DMFD is an Office of Naval Research-sponsored program consisting of three different systems for distributing bulk petroleum from amphibious ships to maneuver force ashore.

Three DMFD Systems

15,000-gallon DMFD

The largest of the three systems is the 15,000-gallon (15k) DMFD system. It is designed for the landing craft air cushion (LCAC), to carry fuel ashore during the first days of an amphibious operation. The 15k DMFD consists of four 3,750-gallon fabric tanks (or bladders), weighing a total of 105,000 pounds when full. It is envisioned that the 15k DMFD would be deployed during the assault phase after facilities are in place for transferring bulk fuel at the beach, and at which time one or more LCAC can

be designated for fuel transport. (Appendix A gives more data on the 15k DMFD.)

3,000-gallon DMFD

The other two systems are designed for ashore mobility. One of these is the 3,000-gallon (3k) DMFD system, which consists of two collapsible bladders secured to a 1077 flatrack. The assembled and filled system is projected to weigh roughly 24,000 pounds and may be moved by the logistics vehicle system (LVS) MK18/A1. Three complete systems and an LVS are expected to be transportable by LCAC simultaneously with 9,000 gallons of product. **The system tested during *Foal Eagle* consisted of two 900-gallon bladders.** Because of fluid sloshing, the 3k may only be moved either when completely empty or full.

400-gallon DMFD

The third system also is designed to be mobile and is capable of being moved by surface from ship to shore, or by air from ship to the using unit. By surface mode, the 400 DMFD can be moved ashore by LVS to forward-deployed units. In the largest configuration, the 400 DMFD consists of ten individual tank modules mounted on a custom pallet. One or more of these tanks may be removed and operated independently. A seven-tank system leaves room for a pump and filter-separator. A small auxiliary pump is mounted on top of the main pump and can be removed for independent operation with a single tank. The modular configuration eliminates significant fluid slosh. Independent tanks can be handled by a 4,000-pound forklift, 5-ton truck, heavy HMMWV (high- mobility multi-purpose wheeled vehicle), or medium- or heavy-lift helicopter.

Hardware Demonstrations

A series of hardware demonstrations have been conducted during recent exercises to test and refine each system. The first of these involved all three systems filled with water during the *RIMPAC (East)* Exercise in May 2000 at Camp Pendleton. The 400 DMFD system was tested again, with diesel fuel, in June 2000 during a combined arms exercise (CAX) at Twenty-Nine Palms.

The most recent demonstration was conducted during *Foal Eagle 00* in Korea with all three systems embarked aboard amphibious shipping (*Essex* ARG) roughly 25 nautical miles offshore. This time, JP-5 was delivered by each system to USMC tactical fuel systems ashore. The demonstration was intended to simulate OMFTS/STOM conditions, the most comprehensive test of these systems to date.

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[1] See also, *Future Naval Fuel Storage and Distribution Systems*, North/McCarthy, CIM D0001671.A1, June 2000; *Class III Requirements in an OMFTS Operational Environment*, Jebo/North, CRM D0002243.A1, August 2000; and *Meeting OMFTS Class III Requirements: Course of Action Development*, CIM D0002749.A1, October 2000.

Foal Eagle 00

Various schedules of events (SOEs) were developed in the months leading up to the demonstration. Originally, two days were scheduled for the test with one complete ship-to-shore-to-ship cycle each day. At a meeting between USMC reps and the PHIBRON commander, it was decided to embark the systems late on day one and run two complete ship-to-shore cycles the following day, disembarking the systems on shore following the second run.

The 15k DMFD was embarked aboard USS *Essex* by LCAC, and the 3k and 400 DMFD systems boarded USS *Ft. McHenry* via LCU (landing craft unit). The 400 DMFD systems were embarked completely assembled. The 15k and 3k DMFD systems were assembled that night from staging positions in their respective well-decks. All systems were fueled the same night or early the next morning. Fuel was to be delivered by each system to a fuel farm established just beyond the high water mark ashore.

Analytic issues

We observed and collected data on the range of variables associated with employment and deployment of each DMFD system. These included the amount of time, personnel, heavy equipment, and storage space required to embark, store, assemble, fuel, load, transit, off-load, and defuel the different systems.

Unlike earlier demonstrations, the embarkation of the DMFD units aboard ship allowed us to capture the complexities of coordination between Navy and Marine Corps personnel, including the support demands of the systems once afloat.[2] Significant questions remain about concepts of employment and changes that might be made to existing and future ships to improve the deployability and employability of naval fuel distribution assets.

The two smaller DMFD systems carry similar volumes of fuel. While there are differences in other aspects, this similarity suggests that the Marine Corps may select one or the other, or perhaps a modified version. Part of our analysis is devoted to a discussion of the virtues of these systems under different employment concepts.

Approach

We began by reviewing the steps and times involved in embarkation through defueling of each system. These provided us with rough measures with which to evaluate the total time required to deliver a given volume of fuel to the beach and beyond. By laying out the variables associated with each step, we were able to gain insight into those routines whose intervals might be shortened through one or more hardware or procedural changes. For example, if the delivery of fuel to the well-deck and DMFD system is constrained by the rate of the shipboard pump, might a larger pump save time? Similarly, would adding personnel reduce the time to assemble each system?

With the individual times for discrete events, we estimated the time needed to supply a set amount of fuel under different employment concepts. Still in question is the best way to use one or a combination of these systems. While the Marine Corps' objective is to limit the footprint ashore, the Navy likely is interested in minimizing the drain on LCAC resources used to transport these systems. Depending on the perspective, one system or combination of systems might be preferred over another. To account for these different viewpoints, we pose two different scenarios and estimate the resources associated with each. Similarly, differences in the characteristics of each system, such as stowed footprint and weight, might be relevant under each of the scenarios. We lay out some of these key determinants.

Scope

The *Foal Eagle* demonstration was limited to the surface delivery of fuel. It is likely that a mix of air and surface craft would be used to move fuel ashore in a contingency. From the test, however, we are not able to comment either on the suitability of one or more of these systems for airborne transport or on the advantages and disadvantages of using such transport.

We also did not address fuel storage capabilities of the amphibious ships. These would be important given that the Marine Corps wants to go to a single fuel (JP-8) and that amphibious ships typically carry both JP-5 and DFM (diesel fuel marine). DFM is used to fuel LCAC and AAV, among other equipment.

One of the existing USMC systems for distributing fuel is the SIXCON. This system uses containers that are large and relatively heavy for the amount of fuel they carry (900 gallons). They may be replaced by one of the smaller DMFD systems. Beyond listing their dimensions in appendix B, we do not compare the SIXCON to the DMFD demonstrators. Such a comparison would be useful in determining the added value of the newer systems.

Limitations

Several factors limited our ability to make judgments about the strengths and weaknesses of each system. For example, both 400 DMFD systems were embarked and staged in the well-deck of the LSD fully assembled. We were therefore not able to capture either true stowed configurations or time to stage and assemble aboard ship. As a proxy for afloat assembly times, we used observations from an ashore assembly test involving a 400 DMFD system using ten tank modules. But even these do not accurately reflect the total assembly time for the other variant of the 400 DMFD, since the pump and filter/separator already had been mounted on the custom pallet.

Though advertised as having a 3,000-gallon capacity, the 3K DMFD used during *Foal Eagle 00* consisted of two 900-gallon bladders. This capacity is expected to increase as the application of technology allows. For this paper, however, we evaluated the existing smaller system.

Both the 400 and 3K DMFD systems are advertised as having ship-to-objective capability. Once afloat, however, these systems cycled from ship to shore. Tactical refueling was demonstrated prior to embarkation aboard ship.

Finally, while two ship-to-shore fueling cycles were scheduled, time and other constraints limited the demo to one fueling cycle for the smaller systems. A second run was made without fuel. This limited the number of observations we were able to make. Also, the lighter load may have decreased transit times during the second run, but probably only marginally.

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[2] The Navy is responsible for delivery fuel to the high water mark. See Joint Publication (JP) 4-03, *Joint Bulk Petroleum Doctrine,* 25 July 1995.

Summary of events and times

Data collection sheets developed by the NFESC identified key information needed for our assessment. We modified these to capture as many of the relevant deployment and employment routines as possible. We were not able to record times for all events. In an actual contingency these systems likely would be embarked pierside, stowed for transit, and then staged in the well-deck for assembly. These are important routines, but they are one-time (or non-recurring) events. Below are the major events. Some are not applicable to every system (e.g., load/ offload for the 15k DMFD).

Table 1. Non-recurring event times (hr/min)

	Essex (LHD)	*McHenry* (LSD)	
Routine/sub-routine	**15k**	**3k**	**400G**
Embark	00:26	00:32	00:12
Stow	N/A	N/A	N/A
Stage	N/A	N/A	N/A
Assemble	1:58	00:50	00:41
System		*00:43*	*00:34*
Porta-berm		*00:07*	*00:07*
Total	**2:24**	**1:22**	**00:53**

One-time events

- Embark
- Stow
- Stage
- Assemble

Core cycle

- Fuel
- Load/secure
- Pre-flight/transit
- Offload
- Defuel
- Load/secure
- Pre-flight/transit

These times should be treated with caution, especially when making comparisons. For example, one of the 400 DMFD units was embarked already assembled on an LVS, thereby decreasing the embark time.[4] Further, the confined spaces of the LCU made it difficult to remove the double-stack of 1077 flatracks onto which the 3k DMFD were to be assembled, skewing the times considerably. Given enough personnel, assembly of the porta-berms could be done during the staging process.

Personnel and equipment required for each non-recurring event varies by system. Table 2 below lists the requirements for each DMFD unit. Figures for personnel reflect the number of individuals involved at different times. With practice, systems could be readily assembled with five or six Marines/sailors. In our judgment, adding personnel would not significantly reduce assembly times, except perhaps for the larger 15k system. A forklift is required to both stow and assemble the 400 DMFD.

One-time events

Table 1 lists times recorded for the non-recurring events observed. They are for single systems. As noted above, the routines followed during the demonstration may not reflect the fielded concept of deployment. Embark times reflect the amount of time it took to unload the DMFD systems from the LCAC and LCU. Rather than stow the gear, DMFD systems were staged in the well-decks of the LHD (15k DMFD) and the LSD (3k/400). Each system was then assembled from its staged position.[3]

Table 2. Single DMFD stowage/assembly requirements

		MHE	
Stow/assembly	**Personnel**	**Stow**	**Assemble**
15k	6-11	4k forklift	
3k	5	4k forklift	
400G (10)	6	4k forklift	4k forklift

[3] Both well-decks were nearly completely empty. Times to embark, stow, stage, and assemble likely would increase as a function of crowding and MHE availability.

[4] Assembly times are from an ashore test done prior to the demo involving ten tanks from staged positions on a hard-pack grinder. They do not include the time required to mount/connect the pump and filter/separator.

Core cycle times

Figure 1 compares core cycle times (CCTs) for each system. Since two of the 3k DMFD and 400 DMFD systems were deployed, the times are averages for the two systems demo'd multiplied by four, the number that may be deployed on one LCAC. Similarly, the times for the 15k system are the average of two complete ship-to-shore cycles. Appendix A provides more detail on the variances of each run.

Evident from the figure is the fact that the 15k system (the largest system) consumes the most time for most of the routines, but also delivers the most fuel. Because of load and unload times for the two mobile systems, however, the core cycle time for 15k DMFD (roughly nine hours) is shorter than the estimated cycle times for four units of either the 3k or 400 DMFD (around ten hours). The difference in cycle time for these smaller systems is negligible, but the amount of product varies.

Also obvious is the time it took to fuel all three systems, especially the 15k DMFD. At an average of nearly five hours, fueling/ defueling routines consumed well over half (62 percent) of the core cycle time. This was due almost exclusively to pumping rates.[5] Table 3 breaks down the percentage of time consumed by routine.

A variety of factors influence the duration of each routine and the total core cycle time. LCAC loading times may depend on experience levels and the number of operators. Weather conditions and distance from shore may shorten or lengthen the time it takes to transit, or may delay transit indefinitely. However, the variability of these factors can't be predicted or won't change appreciably.[6] This suggests that efforts to shorten cycle times should focus on fueling and defueling. These are functions variously of pump size, filter/ separation, and hose diameter, all of which can be changed to reduce time. Table 4 shows fueling and defueling rates. Again, the numbers for the 3k and 400G DMFD are averages for the two systems of each used in the demonstration.

Figure 1. Ship-to-shore-to-ship cycle times by event/total

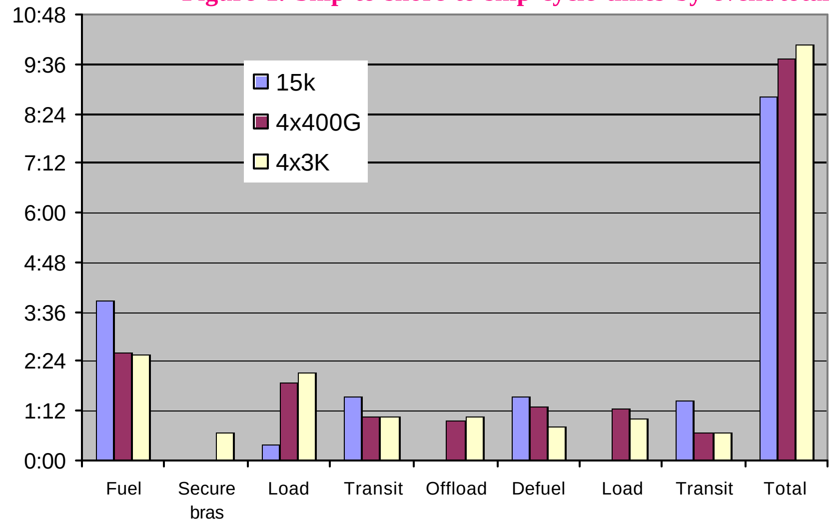


Table 3. Distribution of event times by system (hr/min)

	Essex (LHD)		*McHenry* (LSD)			
Cycle events	**15k**	**% total**	**3k**	**% total**	**400G**	**% total**
Fuel	3:51	44	2:34	26	2:36	27
Secure bras	n/a		0:40	7	n/a	
Load/secure	0:24	5	2:08	21	1:52	19
Transit	1:32	17	1:03	10	1:03	11
Offload	n/a		1:04	11	0:58	10
Defuel	1:34	18	0:50	8	1:18	13
Load LCAC	n/a		1:02	10	1:16	13
Transit	1:28	17	0:42	7	0:42	7
Total	**8:49**	**100**	**10:03**	**100**	**9:45**	**100**

Table 4. Capacities and fueling/defueling rates

	Essex (LPD)		*McHenry* (LSD)[7]
Volumes/rates	**15k**	**3k**	**400G (10)**
Rated capacity (gallons)	15,000	1,800	4,000
Fuel loaded during demo (est)	14,117/13,700	1,600	2,153
GPM (fuel afloat)	65/75	55	55
Rated capacity (GPM)	**200**	**55**	**55**
GPM (defuel ashore)	184/225	138	113
Rated capacity (GPM)	**600**	**600**	**600**

[5] The defueling portion of the demonstration may not have yielded good times. For example, the flow rate during the first cycle may have been limited by the use of a flow meter. The second defueling without the flow meter was somewhat faster, but there was not as much difference in total time since tanks were stripped of as much fuel as possible in preparation for stowing. NFSEC engineers estimate that 90 percent of the fuel was discharged in the first half-hour during the second run. This conforms to the results of a test using water earlier this year at Camp Pendleton.

[6] Load/transit times for the 15k DMFD were reduced somewhat during the second run (see appendix A).

[7] The "fuel loaded" amounts are roughly what went into each of the two systems demo'd, i.e., 2 x 3k and 2 x 400G DMFD.

Although both the 15k and 400 DMFD systems have organic pumps, shipboard and shore-based pumps were used to fuel and defuel each system. The rated pumping capacity of JP-5 to the well-deck aboard the LSD was 55 gpm (gallons per minute) at 35 psi.[8] The anticipated pumping capacity of fuel to the well-deck from JP-5 tanks aboard the LHD was 200 gpm. Actual pumping rates were from 65 gpm on the first run and 75 gpm on the second.

Once ashore, a single 600-gpm trailer-mounted pump sucked fuel from the DMFD systems to the fuel berm. Since the 3k and 400 DMFD systems were fueled and defueled only once, we were not able to observe differences in pumping rates. Nor can we explain why a higher defueling rate was achieved for the 15k system over the 3k/400 DMFDs using the same pump. Removal of the flow meter during the second refueling and defueling of the 15k DMFD improved the flow rate somewhat (from 65 to 75 gpm aboard ship and from 184 to 225 gpm ashore).

Other factors to consider

The above discussion lays out some factors that help distinguish between each of the concept demonstrators. These include fuel capacity, assembly times, stowage space, and MHE requirements. Given differences in the way each system may beemployed, certain comparisons are not helpful. For example, the 15k DMFD is purely a ship-to-shore system, delivering large amounts of fuel to facilities on the beach. Fuel would then be shuttled between the beach and the end-user inland, perhaps using one or the other of the smaller mobile systems. Under certain conditions the ability of the smaller systems to cycle between ships and objectives might obviate the need for the larger system. These considerations aside, certain other factors might be useful in summarizing the characteristics of the DMFD systems.

One of these is the ratio of the assembled weight of each system empty (AW = assembled weight) to the gallons of fuel carried (FC = fuel capacity). All things equal, preference might be given to systems that weigh less and carry more.

Another helpful measure is the ratio of stowed cube (SC) to assembled fuel capacity (FC) in gallons. If storage space were not a consideration, this measure would not be relevant. However, ships loaded with Marines, equipment, and sustainment are very crowded. As with the first ratio, which addresses weight, systems that take up less space for the same amount of fuel will be more desirable (other factors constant). Table 5 summarizes these characteristics.

Columns 2 through 4 list the capacity and STOM/modular capabilities of each DMFD system. Only the 400 DMFD is modular, enabling individual tanks to be removed or multiple products to be carried. While the individual tanks minimize fluid sloshing, the off-road weight restrictions on the LVS limit the number of full tanks that may be carried to seven[9].

This modularity, however, comes at a cost both in terms of stowage space and weight. From columns 5 and 6, we see that the 400 DMFD is heavier and consumes more space than the other two systems.[10] The differences are even more dramatic when we normalize for the amount of fuel each system can carry (shown in the last two columns). For every cubic feet of stowage space required, the 400 DMFD yields 8 gallons of product (a ratio of 1:8). This is well below the ratios of 1:20 and 1:63, for the 3k and 15k DMFD, respectively.

Similarly, a single pound of the 400 DMFD yields a half-gallon of product. This compares to ratios of 1:0.5 and 1:7 for the bladder systems.[11] Weight is most important when considering the LCAC and LVS. Together, these measures provide helpful insight into some of the trade-offs of using more rigid structures vice bladders for transporting liquids.

Not reflected in this table is the complexity of each system. Both the 3k and 15k DMFD systems are easy to assemble and operate. When empty, the different components may be moved by one or two individuals. Each of the tanks that make up the 400 DMFD, however, can only be moved by 4k forklift. When mounted, each must be connected to the custom pallet individually. Over time, repeatedly assembling and disassembling the system might bend or shear these connectors. To shift fuel between tanks, multiple valves must be opened and closed. In the exercise, fuel sensors often gave delayed or inaccurate readings of tank levels. And one of the tank casing ruptured during the fueling routine, possibly because of a faulty the fuel shut-off valve. While these quirks presumably could be fixed, the overall complexity, weight, and stowage space required might outweigh gains from the system's modularity.

400 DMFD with pump and filter/separator

One of the key features of the 400 DMFD is the optional fuel pump and filter/separator. Together these take up three tank positions on the back end of the custom pallet and weigh just over 3,000 lb. In perfect conditions this version yields 2,800 gallons of product in seven tanks. However, the combined weight of the custom pallet, full tanks, and pump with filter/separator exceeds the off-road weight limits on the LVS by roughly 1,800 lb. Thus, only six of seven tanks may be completely filled when the LVS is in an off-road mode with the mounted pump.

Table 5. Key characteristics of DMFD systems

DMFD	Fuel capacity (FC) (gal)	STOM	Modular	Assembled weight dry (AW) (lb)	Stowed cube (SC)	Ratio SC:FC	Ratio AW:FC
15k	15,000	No	No	2,150	240	1:63	1:7
3k	1,800	Yes	No	3,650	88	1:20	1:0.5
400G (10)	4,000	Yes	Yes	8,100	504	1:8	1:0.5

[8] The rated capacity of the pumps servicing the LSD's DFM tanks was estimated at 250 gpm. Placing a larger pump on the JP-5 tanks or filling the DFM tanks with JP-5 would significantly reduce fueling times.

[9] The LVS replacement (LVS-R) has a higher off-road payload that may allow more fuel to be transported.

[10] Stowed cube calculations do not include the dimensions of the pallets. These would presumably ride on the LVS during transit.

[11] The actual weight of the 3k (bladders, braces, bras, and hoses) is roughly 450 lb. Most of the assembled weight comes from the steel flatrack on which it is mounted (3,200 lb.)

Two employment scenarios

Fuel requirements depend on the size of the force and the rate of fuel consumption. The daily fuel requirement of the baseline MEB-sized ground forces in sustained operations has been estimated at around 100,000 gallons per day.[12] We used this figure to calculate the resources needed to meet this requirement using one or a combination of DMFD systems.

Scenario 1: Ship to objective

The 3k and 400 DMFD both are capable of delivering fuel from ships at sea to inland objectives. Under this scenario, four systems would be transported to shore on each LCAC, picked up by LVS, and moved to assault units some distance inland. LCAC/LVS loading and unloading times are estimated from those experienced during the *Foal Eagle* demonstration, as are fueling/defueling rates and transit times, where applicable. We also show the effect of increasing pumping rates afloat and ashore to reflect possible performance improvements. This would include larger shipboard pumps servicing JP-5 storage tanks.[13] Below is a detailed list of assumptions:

- There are four 3k or 400 DMFD per LCAC.
- The 400 DMFD consists of seven tanks due to off-road LVS weight limits.
- LVS/trailer-mounted pumps are already ashore.
- Round-trip from beach to objective = 50 minutes.
- Shipboard fueling rates = 55 gpm per system (one at a time).
- Defueling rates = 25 gpm simultaneously from four hoses with each system.
- DMFD is fueled on LCAC from first run.[14]

Table 6. Scenario 1 results (ship-to-objective w/ 3k/400 DMFD to 100k gallons)

	Demo times		Improved pumping rates	
DMFD	**3k**	**400G**	**3k**	**400G**
Core cycle time (hr)	7.40	8.78	5.70	6.13
Fuel yield/cycle (gal)	7,200	11,200	7,200	11,200
LCAC cycles/day	3.24	2.73	4.21	3.92
Fuel yield/LCAC/day (gal)	23,356	30,625	30,334	43,850
LCAC required	4.28	3.27	3.30	2.28
DMFD required	17	13	13	9

The results are shown in Table 6. Appendix C lists the estimated times for each routine in the core cycle.

The table shows the difference in resources needed to deliver 100,000 gallons of product to inland sites using the 3k DMFD and the 400 DMFD.[15] The differences are driven exclusively by fuel capacity. With core cycle times estimated at nearly nine hours for the 400 DMFD, upwards of three dedicated LCAC and 13 individual DMFD systems would be needed to meet the daily requirement with existing pumping rates on ship. Over four dedicated LCAC and seventeen 3k DMFD would be required to deliver the same volume of fuel as currently sized. The number of LCAC/systems needed drops dramatically if we increase the shipboard fueling rates from the current 55 gpm (for JP-5) to 250 gpm (the capacity of the pump servicing the LSD's DFM storage tanks).

These improvements would reduce core cycle times by 30 percent (from nine to six hours) for the 400 DMFD and consequently the number of LCAC (2.28) and DMFD (nine) needed. We get less of an improvement (23 percent) with the 3k system since it carries less fuel. Even with higher pumping rates, more than three LCAC and thirteen 3k systems would be needed to deliver roughly the same amount of product during a 24-hour period.

Scenario 2: Ship to beach to objective

In the second scenario, fuel is brought to a storage facility on the beach by the 15k DMFD embarked on LCAC. Either the 3k or 400 DMFD would shuttle fuel from the beach to inland sites. As with the two smaller systems in the first scenario, the clock starts once the 15k DMFD is assembled on the LCAC and ready for fueling. For the 15k DMFD, we used the shorter of the two cycles experienced during the demonstration to account for improvements in comfort levels and flow rates. Finally, we assumed that shuttling operations using the 3k/400 DMFD would begin following the complete defueling of the first 15k DMFD on the beach. These shuttle cycles varied for the two smaller systems because of capacity differences. We added 50 minutes of round-trip transit time to objective. Thus, the total time required to meet 100,000 gallon requirement at the objective equals the time to build up fuel on the beach plus the time to deliver it to the objective.

The upper half of table 7 addresses the delivery of fuel to the beach by the 15k DMFD. The lower half of the table shows the number of smaller systems needed to shuttle fuel between the beach and objectives. The first two columns use times observed during the demonstration (where applicable) to calculate the duration of core cycles. Core cycle times in the last two

[12] For the actual requirements, see *Class III Requirements in and OMTFS Operational Environment*, Jebo/North, CNA D0002243.A1, August 2000. A MEU-sized force would require far less fuel during both the assault and sustained operations.

[13] We might also reasonably expect to be able to improve the ashore defueling rates to more closely match the rated capacity of the 600-gpm trailer mounted pumps. Because in this scenario fuel is being delivered directly to units, the vehicle being refueled determines the rate at which fuel can be accepted. This will vary by vehicle. We used 25 gpm from each of four hoses associated with each system. A higher rate or more hoses would reduce core cycle times.

[14] More detailed calculations would account for assembly time on the first day. Doing so would lengthen core cycle times and increase the number of LCAC required. For simplicity, we ignore assembly times.

[15] LCAC/DMFD resources were calculated by dividing the total requirement for fuel (100k) by the amount of fuel delivered by one LCAC/DMFD in one day. The fuel yield equals 24 hours divided by the core cycle time multiplied by the fuel system capacity.

Table 7. Scenario 2 results (ship-to-objective w/ 15k and 3k/400)

15k DMFD to beach	**Demo times**		**Improved pumping rates** (250 gpm afloat/400 gpm ashore)	
Core cycle time (hr)	7.43		4.40	
Fuel yield/cycle (gal)	15,000		15,000	
LCAC cycles/day	3.23		5.45	
Fuel yield/LCAC/day (gal)	48,430		81,818	
15k and LCAC required	**2.06**		**1.22**	
3k/400 DMFD from beach to objective	**3k**	**400G**	**3k**	**400G**
Time 1st LCAC defueled (hr)	6.13	6.13	3.10	3.10
Shuttle cycle time (hr)	2.15	2.89	2.15	2.89
Fuel yield/cycle (gal)	7,200	11,200	7,200	11,200
Shuttle cycles/day	8.30	6.19	9.71	7.24
Fuel yield/day (gal)	59,740	69,321	69,882	81,090
3k or 400 DMFD req ashore	**7**	**6**	**6**	**5**

columns were calculated using improved pumping rates both afloat and ashore. As in the first scenario, defueling rates at the objectives were estimated at 20 gpm.

The lesser of the core cycle times for the 15 DMFD was about 7 hours and 20 minutes. With 15,000 gallons of product per run, 2.06 LCAC could deliver 100,000 gallons of fuel to the beach in seven sorties every 24 hours. If we add the estimated shuttle time for each of the smaller DMFD already ashore (once the first LCAC are defueled), upwards of twenty-two 3k and twenty-one 400 DMFD would be needed to move the fuel inland.

Improving pumping rates would shave 40 percent off the number of hours needed to build-up 100,000 gallons of product on the beach, and by extension the number of dedicated LCAC.[16] With a core cycle time of 4 hours 20 minutes, the number of dedicated LCAC falls from 2.06 to 1.22. The 100,000 gallon daily requirement at objectives could be met with six 3k or five 400 DMFD systems.

Comparing these numbers to the scenario 1 results, and assuming no preference for employment concept, the use of the larger 15k DMFD to build up fuel on the beach requires roughly *half* the LCAC assets. This assumes that pumping rates on ship and ashore at the fuel farm could be improved dramatically. *Also worth noting is that fact that the existing 3k system does not carry enough fuel to be competitive in the first scenario, but it has many attractive features* that would have to be considered if the capacity could be increased. The differences in capacities between the two smaller systems were not significant in the second scenario.

A final note about the scenarios

We made a number of assumptions to simplify the scenarios that may not account for intended design differences in each of the two mobile systems. For example, assuming that tactical vehicles would come to either the 3k or 400 DMFD for refueling rather than the other way around favors the 3k system. This is because it can only be transported either completely full or empty (point-to-point line-haul). With its separate tanks, the 400 DMFD was designed as a true dispensing system, capable of servicing individual or small groups of vehicles some distance away from one another. This may not be the most efficient refueling method, but it's one option offered *only* by the 400 DMFD.

We also assumed that shore-based pumps would be used to draw fuel from the mobile DMFD systems, and that defueling would be done with four hoses per system. This allowed multiple vehicles to be fueled simultaneously from both systems in each scenario. We note, however, that one of the 400 DMFD variants has a pump and four live hoses. Use of this variant would eliminate the need for shore-based pumps.

[16] For simplicity, we estimate the effects of improving afloat and ashore pumping rates for the 15k system only (from 75 gpm to 250 gpm afloat, and from 225 to 400 ashore).[2] Although the fueling rate aboard the LHD was anticipated to be 200 gpm, we assume that a 250-gpm pump could be installed if one does not already exist. Assuming a 400-gpm defueling rate ashore may or may not be realistic, but we wanted to show the magnitude of effect.

Concluding remarks

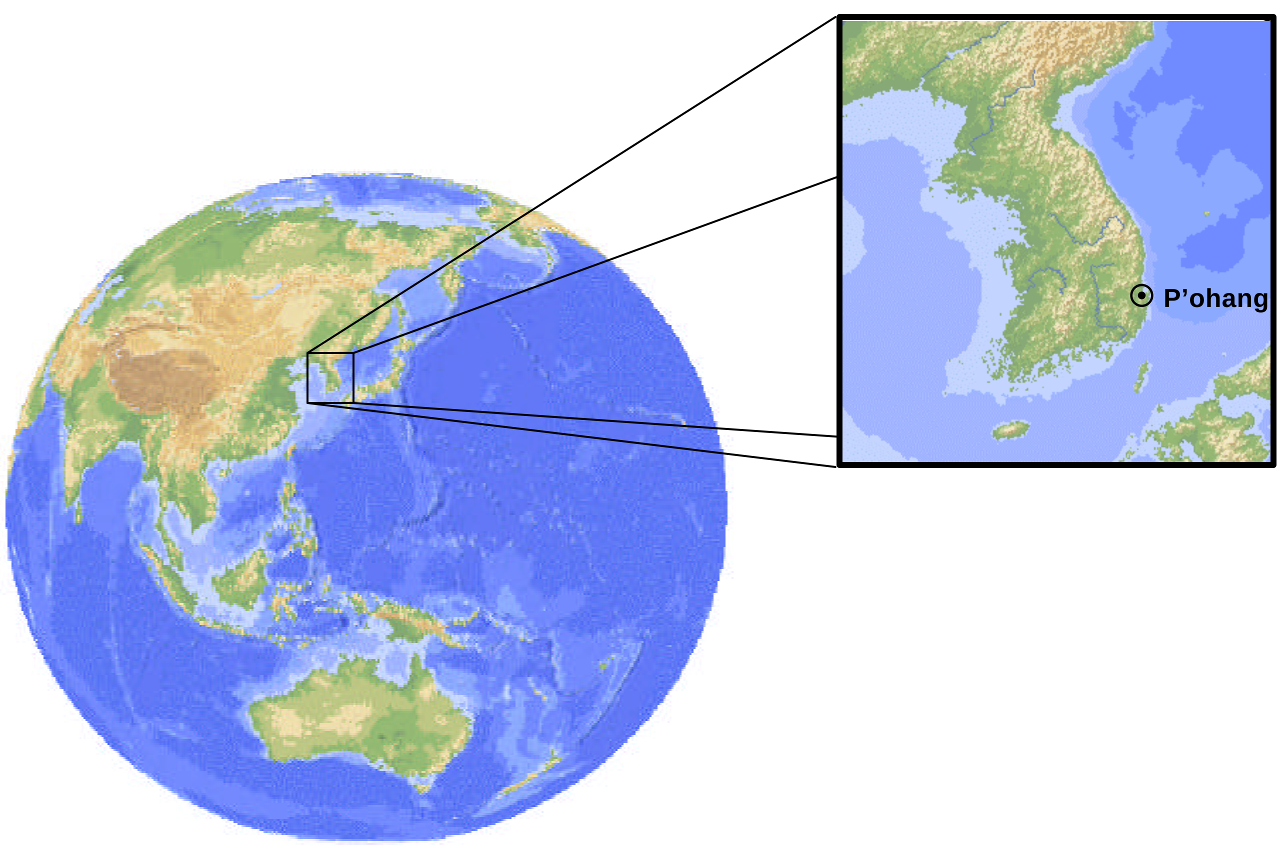
Data collected during the *Foal Eagle 00* demonstration suggest that three DMFD systems could meet the Marine Corps' amphibious-assault fuel-distribution requirements individually or in combination. The real issue is, At what cost? We do not know the dollar cost to field each system. Instead, our limited assessment focused on other non-monetary considerations, to include the demand for Navy transportation assets and afloat storage space. This demand is a function of the different physical and performance characteristics associated with each DMFD demonstrator and the systems that support it: e.g., the LVS, afloat fuel storage capacities, and shipboard/ashore fuel pumps.

The larger 15k DMFD is the closest to fielding. It is easy to assemble and operate, has a small stowed-footprint, and provides the largest volume of fuel for its weight. For Marines, the greatest drawback is that it increases the footprint ashore.

The 3k and 400 DMFD support STOM concepts, but certain characteristics limit their utility. The 400 DMFD is so heavy that it cannot be fully fueled for use off-road—and it would need to be used off-road for conditions that exist on the beach if not beyond. It also takes up a lot of room on the ship, sits high off the ground when on the LVS, and can only be assembled with a forklift. It is fragile and complex. Certain components such as fuel sensors and pressure relief/fuel shut-off valves were unreliable, even though they weren't part of the demonstration. Various Marines involved in the assembly and operation of the system described it as "not for combat" and "over-engineered." While these remarks should not carry the day, they point to system design issues that need to be addressed. Finally, questions remain about the virtues of its modularity. While the individual tanks limit fluid sloshing, a byproduct of having separate tanks, other justifications may not make sense. More analysis is needed on the demand for a HMMWV-mounted system, the need for a true dispensing unit, and the suitability for air delivery given its weight-to-capacity ratio.

The existing 3k system with only 1,800 gallons carries less fuel than the other two systems. Even with four dedicated LCAC, the 3k system barely keeps up with the estimated consumption rates of a MEB-sized force ashore. That said, it has many of the positive characteristics of the larger 15k DMFD and is STOM capable. Increasing itscapacity to 3,000 gallons would put it on a more equal footing with the 400 DMFD in terms of product volume.

Discussions with USMC personnel during the demonstration suggest the possibility of a hybrid system. This system would combine a baffled 3K bladder with a pump and filter/separator unit. The baffles (and restraints) might help minimize fluid sloshing and allow for transport when not completely filled. A baffled system likely would take up more storage space and weigh more than the existing 3K system. However, initial impressions indicate that the system would take up less storage space, would be easier to operate, and could transport more fuel in an off-road mode than the existing 400 DMFD unit. If it had space for a pump (perhaps a big "if'), the 3k DMFD also might be able to function as a dispensing vice line-haul-only system. ❖



Apndx. A:

15k DMFD Data and Observations

This appendix presents greater detail on the individual runs made by the 15k DMFD during the demonstration.

Cycle 1, 15k DMFD

Embark. Unassembled, the 15k DMFD is transported in seven crates; one smaller, long box; two barrels; a box of spill kits; and a pump. These were embarked on LCAC 33 at Dogo beach with the aid of a forklift.

Staging. Once in the well-deck, the DMFD components remained on the deck of LCAC 33, in spot one. They remained there until they were unpacked and were moved to LCAC 81, immediately aft in spot two, during assembly. Thus, the system was never actually staged in the storage spaces of the well-deck.

Assembly. Assembling the 15k DMFD, as noted, consisted of removing components from storage crates and/or moving them to the deck of LCAC 81, where they were assembled. Roughly half of the nearly two hours required for assembly was dedicated to assembling tanks and spill control berms, and attaching hoses. The other half was largely spent tying system components to the deck. A mix of civilian and military labor was used during assembly, with the number of personnel involved ranging from 6 (4 LCAC crew members and 2 Marine engineers—the group that would normally be employed for assembly) to as many as 11 at certain times. Following assembly, operations were suspended for approximately three hours.

Fueling. Fueling began at about 2045. The anticipated fueling rate on the ship was 200 gpm, which would have filled the DMFD with 15,000 gallons of fuel in 75 minutes. This rate was not realized. The system was filled with 14,117 gallons of fuel in 222 minutes, or three hours and 42 minutes. This equates to an actual pumping rate of about 64 gpm. Additional time was required to secure fueling, remove the fueling hose, and make final checks to the DMFD's tie-downs. Following fueling, operations were suspended for approximately five hours; LCAC 81 remained in the well-deck, with full tanks, until about 0600 30 October.

Loading. Some 20 minutes were required to load personnel on the LCAC and make final checks. Such loading and predeparture checks are common to most LCAC operations.

Transit to beach. Actual feet wet/feet dry transit time was about an hour, with LCAC 81 averaging about 25 knots for the transit. Sea conditions were described by the craftmaster as one to three foot with three-to-five-foot swells. The transit to the beach occurred with following seas and winds. Factors adding to the total time were loading personnel, starting main engines, coming up on cushion, and flying out of the well-deck. Of note, the starboard engine stalled when LCAC 81 first attempted to come up on cushion. Because of this, nearly one half hour elapsed between the first time the LCAC attempted to come up on cushion and when she went feet wet.

Defueling. A defueling rate of approximately 600 gpm was anticipated, which would have removed the 14,117 gallons of fuel in about 24 minutes. Actual defueling operations took some 76 minutes. Since flow meters did not function on either the DMFD or the pump, it is not possible to know exactly how much fuel was removed from the system. Some fuel was left in each tank, with tank 4 possibly retaining as much as 100 gallons or more. If an estimate of 14,000 gallons is used, the actual pumping rate realized during defueling was about about 184 gpm. Personnel blamed the flow meter on the DMFD and the need to run additional hose lengths to the LCAC from the pump for at least some of the the slower rate experienced. Additional time during the defueling evolution was spent checking for leaks prior to commencing defueling, staging and connecting hose sections from the pump on the beach, and disconnecting and removing those sections once defueling was complete.

Transit to the ship. Although the total time for this evolution was less than that for the transit to the beach, the feet-wet to feet-dry period was slightly longer despite the lighter load. Although sea conditions were the same as for the inbound transit, LCAC 81 was proceeding up sea and upwind. The return transit was notably rougher than the inbound trip.

The total time for the entire evolution was approximately 12 hours and nine minutes. This number does not include times when operations were suspended. Times associated with each routine are displayed below.

Figure 2. Cycle 1, 15k DMFD

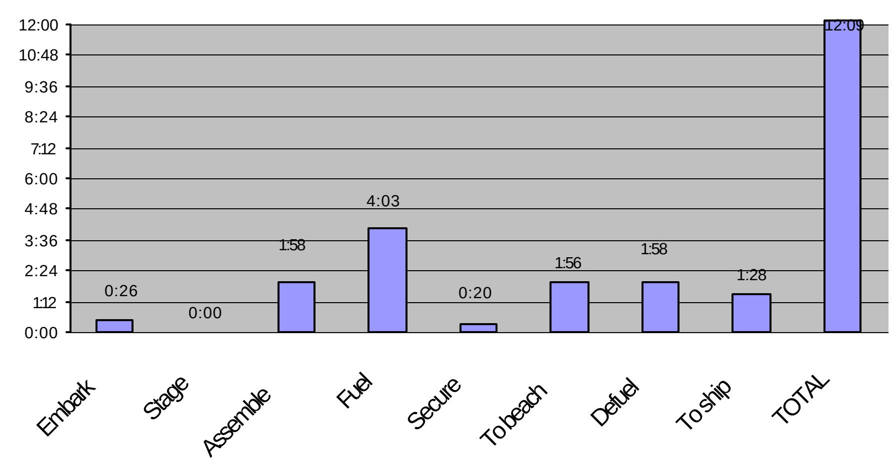
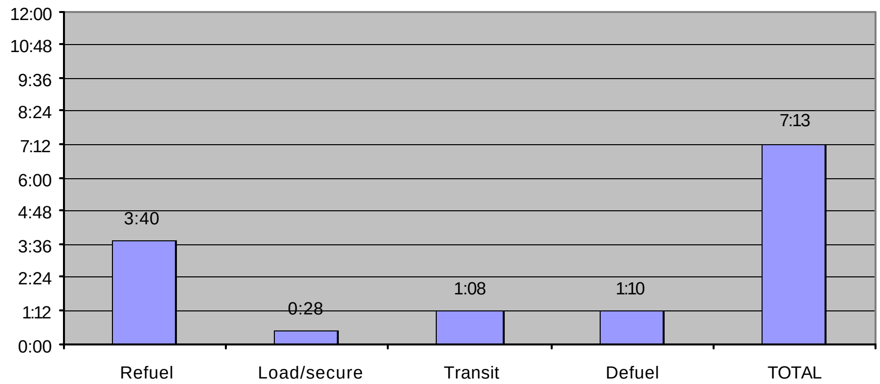


Figure 3. Cycle 2, 15k DMFD



Cycle 2, 15k DMFD

Refueling. It was impossible to know exactly how much fuel was pumped into or out of the system during Cycle 2, since flow meters were removed in an effort to improve cycle times. Subject matter experts on the 15k DMFD estimated that as many as 430 fewer gallons may have been pumped in than during the first cycle. We therefore use an assumption of 13,700 gallons to estimate the pumping rate without the flow meter. Using this assumption, the fueling rate without the flow meter was approximately 75 gpm, an improvement of about 10 gpm over the previous evolution. Securing tie-downs was also accomplished more rapidly than for Cycle 1. There was also a slight spillage, amounting to perhaps two cups of fuel, when the flow meter was removed before refueling began.

Loading. Time required for this evolution was roughly similar to that for Cycle 1.

Transit. Transit time was somewhat shortened, in part because the LCAC came up on cushion and flew out of the well-deck at a more normal speed.

Defueling. Defueling was speeded, in part because of the absence of a flow meter, but as with fueling, it was impossible to know exactly how much fuel was removed. A reasonable assumption, however, is that almost all of the estimated load was removed, because personnel folded the fuel bladders to get as much fuel as possible out of them in preparation for stowing. Assuming that 13,700 gallons were removed in the 61 minutes of the evolution dedicated to actual pumping, the flow rate was about 225 gpm. An additional nine minutes were dedicated to running and connecting hose sections. Personnel made no checks for leaks during this evolution, as they did during Cycle 1. Times associated with each routine are shown in Figure 3.

Comparison of core cycle times

We use the term "core cycles" to refer to those activities that are done on every trip—thus, they do not include embarkation, staging, assembly, or breakdown. Since there was no return transit to the ship in the second cycle, we have re-used the time of the first as an approximation.

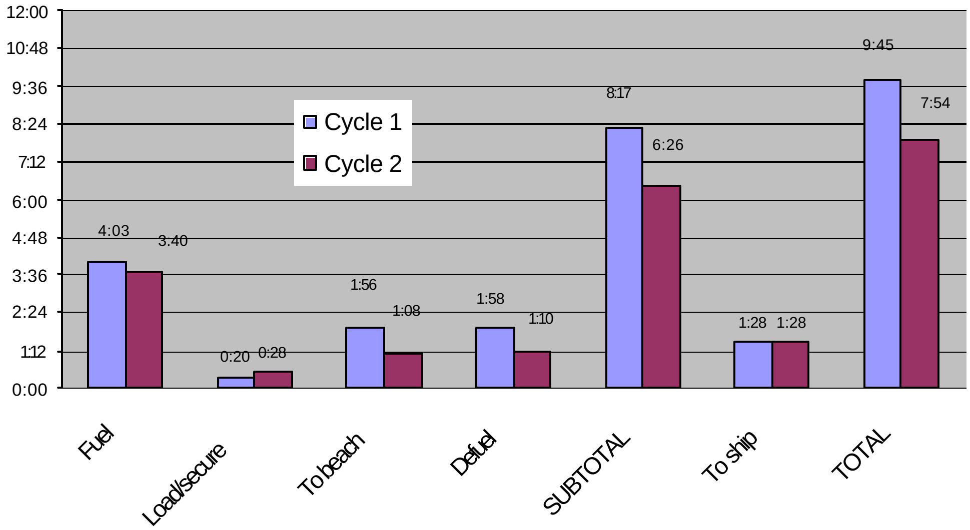
In figure 4, the second core cycle shows some improvements over the first. Time spent fueling was so mewhat shortened by not using a flow meter. Time for transit to the beach was shortened, as the craft master had learned to come up on cushion with less hesitation when carrying the DMFD. Time for refueling was also shortened; non-use of the flow meter was again claimed as a factor—although as with fueling, there was no way to know how much fuel was pumped.

15k DMFD issues

Pumping rate on ship. Anticipated to be about 200 gallons per minute, the pumping rate was actually only about 67 gpm on the first fueling evolution, and perhaps 77 gpm on the second. Since a flow meter was not used, and an undetermined amount of fuel was left in the tanks after the first defueling evolution, it is not possible to know exactly how much fuel was pumped, and therefore what the exact fueling rate was during the second fueling evolution.

Pumping rate ashore. This was anticipated to be about 600 gpm, but was actually about 200 during the first offload and a little higher the second. This resulted in offload times of about 75 and 60 minutes, respectively (again, it is not known exactly how much fuel was offloaded in the second evolution, but it may have been as much as 400 gallons less). The use of a flow meter was cited as a problem the first time, and the need to run additional hose sections to the LCAC may have been a factor in both. The same number of hose sections was used in each, so it is unknown what the exact impact of fewer sections would be.

Figure 4. Comparison of core cycle times, 15k DMFD



Spill containment. Sides of some of the small plastic berms placed below the tanks collapsed while underway on the LCAC. This problem was somewhat mitigated through use of additional tie-downs, but containment of any spill begun while underway is suspect. LCAC crewmembers were concerned that flying debris from a malfunction, or enemy or friendly fire could precipitate a spill. There was no way to know whether a spill had begun while underway, and it was unclear what could be done about it short of throwing leaking systems over the side.

Sloshing. The movement of the fuel within the tanks had some effect while coming up on cushion in the well-deck. Initial efforts to compensate caused the starboard engine to stall. The delay experienced was slight. To avoid this in the future, crewmembers noted that craftmasters should be instructed to come up on cushion more rapidly than usual. This would entail accepting some bumping into well-deck bulkheads.

Supportiveness to STOM. Several individuals noted that the 15,000-gallon system, which delivers its fuel to a fuel farm on the beach, does not support the STOM requirement for moving support infrastructure from the ship to the objective. ❖

HQ USMARFORPAC Camp H.M. Smith, Hawaii

Apndx B:

DMFD Weights/Dimensions

Table 8 summarizes the weights and dimensions of each DMFD system.

Table 8. DMFD Weights/Dimensions

DMFD	Components	LxWxH	Stowed weight	Total cube (ft)	Assembled weight (lb)
15k	5 pallet boxes	4x4x3’	2,500 lb	240	2,150[17]
	5 hose sections	12’ x 4” diam	180 lb		
Total				240	2,150
3k	1 pallet box	4x4x3’	500 lb	48	350
	1 non-standard box	2x2x10’	166	40	100
	1 1077 flatrack	8x24’	3,200		3,200
Total				88	3,650
400G	10 tank modules	44x44x45”	6,000	504	6,000
	1 fuel pump module	44x95x70”	2,365		
	1 filter/separator	44x44x69”	650		
	1 pallet/manifold (w/ “headache rack”)	250x96x54”	2,100		2,100
Total	10 tanks/pallet			504	8,100
SIXCON	1 container (900 gal)	78x96x48”	2,600	208	2,600

[17] This estimate was provided by NFESC.

Apndx C:

Scenario Core Cycle Times

Core cycle times used in the scenario calculations were lower than those recorded during the demonstration. This is mostly due to our assuming that certain routines would not vary much. For example, we do not believe that the time it takes to load and unload the 3k and 400 DMFD to/from the LCAC would differ dramatically, especially since proficiency will be gained through experience. Based on this reasoning, we used 15 minutes to offload and 20 minutes to load the LCAC for each system on the beach. Thus 60 minutes are required to offload four 3k or 400 DMFD from the LCAC and 80 minutes are required to load. Fueling and defueling times are based on flow rates that we might not have experienced during the exercise but might be achieved. We used 25 gpm for defueling at four points for each system. Table 9 lists times for each routine used to calculate the core cycle.

Table 9. Core cycle times (for scenarios)

	Demo-based times			Improved pump rate		
Routine	**3k**	**400G**	**15k**	**3k**	**400G**	**15k**
Fuel/secure	131	204	220	29	45	60
Pre-flight/transit	63	63	78	63	63	78
Offload	60	60	N/A	60	60	N/A
To TAA	25	25	N/A	25	25	N/A
Defuel	18	28	70	18	28	38
To beach	25	25	N/A	25	25	N/A
Load/secure	80	80	N/A	80	80	N/A
Transit	42	42	88	42	42	88
Total (hr)	7.40	8.78	7.43	5.70	6.13	4.40

Among other things, one could argue that transit times should not vary for the 3k, 400G, and 15k DMFD. However, during the demonstration they did. This was due to the distance each ship was from shore, the local traffic, and the comfort levels of the LCAC crew. We may or may not experience these differences in an actual operation. ***Changing any one of these variables would affect core cycle times and the number of LCAC/ DMFD systems required.***❖

APPENDIX B

D-Day Mobile Fuel Distribution
(DMFD)

Foal Eagle Fleet Demonstration

29- 31 Oct, 2000
Pohang, South Korea

Naval Facilities Engineering Service Center
1100 23rd Ave
Port Hueneme, Calif. 93043-4370

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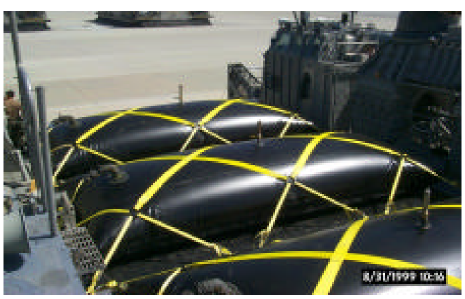
D-Day Mobile Fuel Distribution
(DMFD)
Fleet Demonstration, Foal Eagle-00

Purpose: The purpose of this document is to provide the test plan and procedure to demonstrate the suitability and effectiveness of the D-Day Mobile Fuel Distribution (DMFD) system developed by the Naval Facilities Engineering Service Center (NFESC). The demonstration will be conducted during the Foal Eagle-00 exercise.

Background: D-Day Mobile Fuel Distribution (DMFD) is an Office of Naval Research sponsored program. The program objective is to develop the capability to provide ship-to-shore delivery of bulk fuel during the initial stages of an amphibious assault. The program resource sponsor is OPNAV N85. Three individual fuel delivery concepts are under development.

- The 15,000-gallon D-Day Mobile Fuel Distribution System (15k DMFD) is designed to maximize the LCAC platform's ability to carry fuel ashore during the initial days of an amphibious operation. The 15k DMFD consists of four 3,750-gallon fabric tanks, resulting in a load of approximately 53 tons for the LCAC.



- The 3,000-gallon D-Day Mobile Fuel Distribution System (3k DMFD) is designed to be a mobile system. The 3k DMFD consists of two collapsible bladders secured to a 1077 flatrack. The assembled and filled system (12 tons) is readily moved by the LVS MK48/18A1. Three complete systems and one LVS MK 48/18A1 can be transported simultaneously by LCAC to deliver 9,000 gallons of product. The resulting cargo load seen by the LCAC is approximately 60 tons.

- The 400-gallon D-Day Mobile Fuel Distribution System (400 DMFD) is designed to be a mobile system. The 400 DMFD consists of a series of knockdown tanks that can be handled individually or in multiples on a dedicated transport pallet. When installed on the transport pallet the tanks are manifolded together so that they can be filled and discharged through a single fitting. The system also includes a pump module and filter/separator module that can interface with the transport pallet in place of tanks. Individual containers can be handled by 4K rough terrain forklift, 5-ton truck, or as internal or external helicopter cargo. The assembled system (pallet, tanks, pump, filter/separator) is readily moved by the LVS Mk48/18A1.

Mission/Concept of Operations: The mission of DMFD is to transport fuel from ship to shore during the initial stages of an amphibious assault in support of the Marine Corps assault forces. It is envisioned that the DMFD will be deployed immediately following the assault echelon at which time one or more LCACs can be designated for fuel transport. Each of the 3 systems has specific support requirements, thus differing concept of operations.

- The 15k DMFD requires an LCAC be dedicated to hauling fuel as the system is attached to the deck of the LCAC, precluding that craft's use for other efficiency.missions. The 15K DMFD also requires a beach unloading station be constructed to accept fuel at the beach. Fuel will be ferried from the amphib ship to the beach and offlaoded at the beach into the tank farm/beach unloading station on the beach.

- The 3k DMFD requires sufficient lay down area aboard the amphib ship to assemble and fill the system. The 3k DMFD can be staged and filled aboard the amphib while LCACs perform other missions. When ready, any available LCAC can be tasked to haul the 3k DMFD from ship to shore. On shore, an LVS Mk 48/18A1 can be used to remove the 3k DMFD from the LCAC, or the system can be pumped out into the beach unloading station similar to the 15k DMFD. The 3k DMFD can move forward immediately aboard an LVS to support the advancing assault, or be staged on the beach for retrieval at a later time. Empty 3k DMFD will be returned to the amphib for refill.

- The 400 DMFD requires sufficient lay down area aboard the amphib ship to assemble and fill the system. The 400 DMFD can be staged and filled aboard the amphib while LCACs perform other missions. When ready, any available LCAC can be tasked to haul the 400 DMFD from ship to shore. Like the 3k DMFD, the 400 can follow in trace, be pumped out into the beach unloading, or be staged at the beach for later retrieval. The 400 DMFD has the additional flexibility of being able to operate from other platforms besides the LCAC and LVS. Individual 400 DMFD containers can be slung as external cargo under light, medium or heavy lift helicopters, or transported on 5-ton trucks. Additionally, individual 400 DMFD tanks can be staged with its auxiliary pump and used as a fuel dispensing system, or married to existing Helicopter Expedient Refueling System (HERS) hardware for Forward Arming and Refueling Point (FARP) operations.

Test Objective: The objective of the fleet demonstration is to exercise the systems in an operational environment using actual fuel to demonstrate and validate the functionality and suitability of the system designs.

Issues: A critical issue raised during the development of the DMFD is the ability of the amphibious ships to provide fuel in sufficient quantity and at an adequate flowrate to the well deck for transport ashore. This aspect of the DMFD and ship interface will be demonstrated in addition to well deck operations and beach unloading to evaluate overall overall efficiency.

Test Scenario/Schedule: Figure 1. Is a graphical representation of the Foal Eagle-00 concept of operations for the DMFD demonstration.

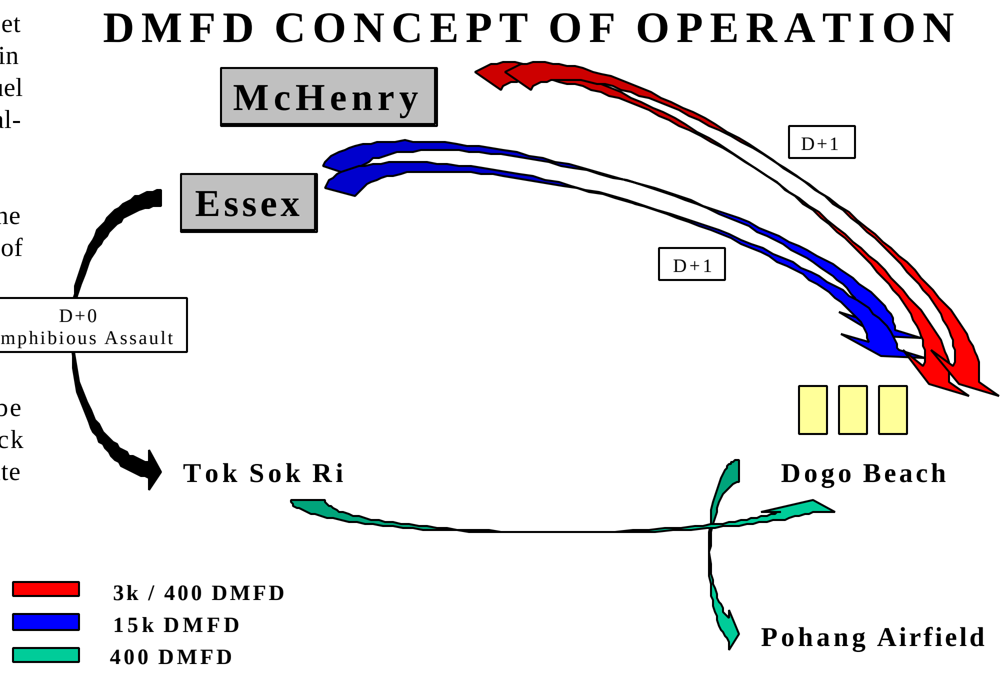


Figure 1. DMFD Concept of Operation during FE-00

The 3k DMFD and 400 DMFD systems will be embarked on the USS Ft. McHenry (LSD-43) from Dogo Beach following the initial amphibious assault exercise on 29 October, 2000. The 15k system will be deployed aboard the USS Essex (LHD-2). Evaluations of the systems will run concurrently. A detailed schedule of events for each of the systems by day is provided below. There is also an alternative single day schedule should it be required due to unforeseen circumstances.

DMFD DETAILED SCHEDULE OF EVENTS FOR USS ESSEX AND USS FORT McHENRY

(DD+1=30 OCT)

DD	Start	Stop	Event
+0	1200	1400	move DMFD equipment from MEC P to Dogo Beach
			DMFD 15k from USS Essex (LHD-2)
+0	TBD	+ 2hr	transfer DMFD 15K system to USS Essex
+1	0700	0800	Assemble 15k DMFD on LCAC deck (LCAC crew, USMC 1391)
	0800	0915	Fill 15k system with fuel. (Approx fill time = 1.25 hrs at 200 gpm)
	0915	0930	LCAC preflight checkout
	0930	1030	Transport fuel to Dogo Beach (25 mi standoff at 25 knotts)
	1030	1100	Offload fuel on beach (time to offload demonstrated during ATD)
	1100	1115	Gripe empty 15k system for return to USS Essex
	1115	1130	LCAC preflight check out
	1130	1230	LCAC return to USS Essex
	1230	1500	Evaluate LCAC Inflight Fuel Transfer (LIFT) system
	1500		LCAC and crew secures for the day
+2	0800	0915	Refill DMFD 15k (approx fill time 1.25 hr at 200 gpm)
	0915	0930	LCAC preflight checkout
	0930	1030	LCAC transports fuel to Dogo Beach (25 mi standoff at 25 knotts)
	0930	1030	Load 15k pallet boxes and ancillary equipment on LCU for transit to Dogo Beach

DD	Start	Stop	Event
	1030	1300	LCU transits to Dogo Beach (25 mi standoff at 10 knotts)
	1030	1100	Offload fuel on beach (time to offload demonstrated during ATD)
	1100	1400	pump residual fuel from systems (100 gal/tank) using HERS pump and de-drumming manifold, fold system and repack into shipping crates (LCAC crew and USMC 1391)
	1400	1415	LCAC preflight check out
	1415	1515	LCAC returns to USS Essex, **MISSION COMPLETED**
			DMFD 3k and DMFD 400 from USS McHenry (LSD-43)
+0	TBD	+2hr	Transfer DMFD 3K and DMFD 400 to USS Ft McHenry DMFD 400
	TBD	+1.5hr	Assemble DMFD 400 dispensing configuration, fill with approx 1000 gal (USMC 1391)
	TBD	+.25hr	Load DFMD 400 onto LCAC/LCU for transit to beach
	TBD	+1hr	Return DMFD 400 to USS Ft McHenry
	2000	2030	Assemble ten (10) 400 gal tanks (USMC 1391)
	2000	2030	Install pallet on 1077 flatrack and position in "porta berm"
	2030	2130	Install ten (10) tanks on pallet and connect to manifold
	2030	2115	Fill system (filling 6 tanks, 2280 gal total at 50 gpm (dispensing system preassembled)
	2130	2215	Fill system (filling 6 tanks, 2280 gal total at 50 gpm

DMFD 3k

DD	Start	Stop	Event
+0	2000	2045	Assemble two (2 systems).
	2215	2315	Fill two (2) systems (1800 gal/system at 50 gpm = 65 min).
+1	0700	0800	Load onto LCAC using LVS (5 min to pick up w/LVS, 10 in to position on LCAC/ unit).
	0800	0900	Gripe four systems (LCAC crew).
	0900	0915	LCAC preflight check out.
	0915	1015	Transport fuel to Dogo Beach (25 mi standoff at 25 knots).
	1015	1045	Retrieve first system with LVS and position on beach for offload.
	1045	1100	Offload first system (approx pump rate 150 gpm).
	1045	1115	Retrieve second system with LVS and position on beach for offload.
	1115	1130	Offload second system (approx pump rate 150 gpm).
	1115	1130	Retrieve third system and position on beach for offload (retrieval of rear mounted systems goes much faster as LVS operator is working on flat deck rather than ramp).
	1130	1145	Retrieve fourth system and position on beach for offload (retrieval of rear mounted systems goes much faster as LVS operator is working on flat deck rather than ramp).
	1130	1145	Offload third system (approx pump rate 150 gpm).
+1	1145	1200	Offload fourth system (approx pump rate 150 gpm).
	1145	1200	Load first system back onto LCAC.
	1200	1215	Load second system back onto LCAC.
	1215	1230	Load third system back onto LCAC.
	1230	1245	Load fourth system back onto LCAC.
	1245	1330	Gripe four (4) mobile systems to deck of LCAC.
	1330	1345	LCAC preflight check out.
	1345	1445	Return to McHenry.
	1445	1515	Retrieve first system with LVS and position in "porta berm" for refill.
	1515	1600	Fill first system.
	1515	1545	Retrieve second system with LVS and position in "porta berm"
	1545	1600	Retrieve third system with LVS and position in "porta berm".
	1600	1645	Fill second system.
	1600	1615	Retrieve fourth system with LVS and position in "porta berm".
	1645	1730	Fill third system.
	1730	1815	Fill fourth system.
+2	0700	0800	Load onto LCAC using LVS (5 min to pick up w/LVS, 10 min to position on LCAC/ unit).
	0800	0900	Gripe four systems (LCAC crew).
	0900	0915	LCAC preflight check out.
	0915	1015	Transport fuel to Dogo Beach (25 mi standoff at 25 knots).
	1015	1045	Retrieve first system with LVS and position on beach for offload.
	1045	1100	Offload first system (approx pump rate 150 gpm).
	1045	1115	Retrieve second system with LVS and position on beach for offload.
	1115	1130	Offload second system (approx pump rate 150 gpm).
	1115	1130	Retrieve third system and position on beach for offload (retrieval of rear mounted systems goes much faster as LVS operator is working on flat deck rather than ramp).
	1130	1145	Retrieve fourth system and position on beach for offload (retrieval of rear mounted systems goes much faster as LVS operator is working on flat deck rather than ramp).
	1145	1200	LCAC preflight check out.
	1200	1300	LCAC return to USS Ft. McHenry, **MISSION COMPLETED.**

DMFD Alternate Single day Schedule

DD	Start	Stop	Event
+0	1200	1400	Move DMFD equipment from MEC P to Dogo Beach.

DMFD 15k from USS Essex (LHD-2)

DD	Start	Stop	Event
+0	TBD	+ 2hr	Transfer DMFD 15k system to USS Essex.
+1	0400	0500	Assemble 15k DMFD on LCAC Deck.
	0500	0615	Fill 15k system with fuel (Approx fill time = 1.25 hrs at 200 gpm).
	0615	0630	LCAC preflight checkout.
	0630	0730	Transport fuel to Dogo Beach (25 mi standoff at 25 knotts).
	0730	0800	Offload fuel on beach (time to offload demonstrated during ATD).
	0800	0815	Gripe empty 15k system for return to USS Essex.
	0815	0830	LCAC preflight check out.
	0830	0930	LCAC return to USS Essex.
	0930	1045	Refill DMFD 15k (approx fill time 1.25 hr at 200 gpm).
	1045	1100	LCAC preflight checkout.
	1100	1200	LCAC transports fuel to Dogo Beach (25 mi standoff at 25 knots).
	1100	1200	Load 15k pallet boxes and ancillary equipment on LCU for transit to Dogo Beach.
	1200	1430	LCU transits to Dogo Beach (25 mi standoff at 10 knotts).
	1200	1230	Offload fuel on beach (time to offload demonstrated during ATD).
	1230	1530	Pump residual fuel from systems (100 gal/tank) using HERS pump and de-drumming manifold, fold system and repack into shipping crates.
	1530	1545	LCAC preflight check out.
	1545	1645	LCAC returns to USS Essex, **MISSION COMPLETED.**

DMFD 3k and DMFD 400 from USS McHenry (LSD-43)

DD	Start	Stop	Event
+0	TBD	+ 2hr	Transfer DMFD 3k and DMFD 400 to USS Ft. McHenry DMFD 400.
	TBD	+1.5 hr	Assemble DMFD 400 dispensing configuration, fill with Approx 1000 gal (USMC 1391).
	TBD	+.25hr	Load DFMD 400 onto LCAC/LCU for transit to beach .
	TBD		Return DMFD 400 to USS Ft. McHenry.
	2000	2030	Assemble ten (10) 400 gal tanks (USMC 1391).
	2000	2030	Install pallet on 1077 flatrack and position in "porta berm".
	2030	2130	Install ten (10) tanks on pallet and connect to manifold.
	2030	2115	Fill system (filling 6 tanks, 2280 gal total at 50 gpm) (dispensing system preassembled).
	2130	2215	Fill system (filling 6 tanks, 2280 gal total at 50 gpm).

DMFD 3k

DD	Start	Stop	Event
	2000	2045	Assemble two (2 systems).
	2215	2315	Fill two (2) systems (1800 gal/system at 50 gpm = 65 min).
+1	0600	0700	Load onto LCAC using LVS .
	0700	0800	Gripe four systems.
	0800	0815	LCAC preflight check out.
	0815	0915	Transport fuel to Dogo Beach (25 mi standoff at 25 knotts).
	0915	0945	Retrieve first system with LVS and position on beach for offload.

DD	Start	Stop	Event
	0945	1000	Offload first system (approx pump rate 150 gpm)
	0945	1015	Retrieve second system with LVS and position on beach for offload.
	1015	1030	Offload second system (approx pump rate 150 gpm).
	1015	1030	Retrieve third system and position on beach for offload retrieval of rear mounted systems goes much faster as LVS operator is working on flat deck rather than ramp).
	1030	1045	Retrieve fourth system and position on beach for offload (retrieval of rear mounted systems goes much faster as LVS operator is working on flat deck rather than ramp).
	1030	1045	Offload third system (approx pump rate 150 gpm).
	1045	1100	Offload fourth system (approx pump rate 150 gpm).
	1045	1100	Load first system back onto LCAC.
	1100	1115	Load second system back onto LCAC.
	1115	1130	Load third system back onto LCAC.
	1130	1145	Load fourth system back onto LCAC.
	1145	1230	Gripe four (4) mobile systems to deck of LCAC.
	1230	1245	LCAC preflight check out.
	1245	1345	Return to McHenry.
	1345	1415	Retrieve first system with LVS and position in "porta berm" for refill.
	1415	1500	Fill first system.
	1415	1445	Retrieve second system with LVS and position in "porta berm".
	1445	1500	Retrieve third system with LVS and position in "porta berm".
	1500	1545	Fill second system.
	1500	1515	Retrieve fourth system with LVS and position in "porta berm".
	1515	1530	Load first system back on LCAC.
	1545	1600	Load second system back on LCAC.
	1545	1630	Fill third system.
+1	1630	1715	Fill fourth system.
	1630	1645	Load third system back on LCAC.
	1715	1730	Load fourth system back on LCAC.
	1730	1815	Gripe four (4) mobile systems to deck of LCAC.
	1830	1845	LCAC preflight checkout.
	1845	1945	Transport fuel to Dogo Beach (25 mi standoff at 25 knotts).
	1945	2015	Retrieve first system from LCAC.
	2015	2045	Retrieve second system from LCAC.
	2045	2100	Retrieve third system from LCAC.
	2100	2200	Retrieve fourth system from LCAC.
	2200	2215	LCAC preflight check out.
	2215	2315	LCAC return to USS Ft. McHenry, **MISSION COMPLETED.**

Test Organization/Command & Control: The Following personnel/agencies are responsible for the following areas of the Concept Demonstration:

a. Concept Demonstration OIC. CWO-4 Collins, 3rd FSSG G-3. CWO-4 Collins has been the lead DMFDS planner per reference (a) and will be the OIC for the DMFDS Concept Demonstration. He will be responsible for the coordination of all DMFDS Support Team activities to conduct the concept demonstration.

b. DMFDS Hardware OIC. Mr Chip Nixon, Mr. Buck Thomas, and Mr. Mark Miller from Naval Facilities Engineering Service Center (NFESC) will be responsible for the deployment and operation of the DMFDS hardware. They will coordinate with CWO-4 Collins for all logistic support and operational guidance.

c. USMC Tactical Fuel Site OIC. CWO-2 Lizardi (3rd FSSG, 9th Engr Spt Bn) will be the OIC for the USMC Tactical Fuel Site. He will be responsible to CWO-4 Collins for the receipt, storage and discharge of JP-5 fuel received and issued at Dogu Beach from USMC Tactical Fuel System.

d. Concept Demonstration Documentation Team. Mr. McCarthy from Center of Naval Analysis (C.N.A. Washington D.C.) and Mr Chip Nixon will coordinate the gathering of technical and operational data during the concept demonstration.

e. Fleet Assessment Analysis Tiger Team. Mr Shujie Chang, MARFORPAC Science Advisor and CWO-4 Ray, MARFORPAC Bulk Liquids Officer will coordinate with the Concept Documentation Team after the exercise on 1 Nov to develop the DMFDS Fleet Assessment Analysis.

f. VIP Coordination OIC. Mr Shujie Chang and CWO-4 Giambruno, I MEF Bulk Liquids Officer will coordinate and manage all VIP activities during the concept demonstration. They will coordinate with CWO-4 Collins to ensure VIP visits do not impact operations. CWO-4 Giambruno will provide Concept Demonstration PME and tours for VIPs at the exercise site and onboard the amphibious shipping.

g. Combined Forces Command Coordination. Maj Malapit (U.S. Army) and LtCmdr Lee (ROK Navy) from the CFC, C-4/POL will provide translation and ROK military liaison services for the DMFDS Support Team.

Test Equipment: The following test equipment has been shipped to Pohang, South Korea to support the DMFD Foal Eagle-00 demonstration.

1 DMFD 400 gal. system transport pallet with 10 tanks

1 DMFD 400 gal. system transport pallet w/7 tanks, pump module, and filter separator module

1 ISO Shipping Container #USAA 013 192 9 containing the following:

15k DMFD Boxes (6)

1-4. Tank with Berm (4) (3 boxes with backpack spill response kit).

5. Restraints and manifold pieces.

6. Long box with hoses and push broom.

3k DMFD Boxes (3)

1-2. 3k System consisting of:

a. two (2) tanks coated with extra urethane.
b. one (1) berm with angle bracket supports.
c. two (2) track belts.
d. two (2) flatrack rear tie down devices.
e. system restraint consisting of:
   1. 18 uprights
   2. 18 retaining pins
   3. 2 restraint halves
   4. 8 top/bottom tie clips
   5. 3 ratchet binders
f. two (2) manifold hoses (2" unisex x 2" FM camloc)
g. two (2) unisex x 2" MPT fittings
h. one (1) 2" camloc (male/male/ FM) wye drilled for pressure gage
i. one (1) 4" FM camloc x 2" male camloc adapter
j. two (2) 4" male camloc x D-1 adapter

1. Long box containing (24) pipes for restraints, (8) 2x12x60" dunnage, and broom

Training Box

a. two (2) tanks coated by FFF
b. one (1) berm with angle bracket supports
c. two (2) track belts
d. system restraint (original) consisting of:
   1. 18 uprights
   2. 18 retaining pins
   3. 2 restraint halves
   4. 8 top/bottom tie clips
   5. 2 ratchet binders
e. two (2) manifold hoses (2" MPT both ends)
f. three (3) back pack spill response kits
g. personal gear consisting of:
   1. Redwing insulated boots 12D
   2. Coverall (short sleeve)
   3. Coverall (long sleeve)
   4. Coverall (insulated)
   5. Insulated bibs
   6. Wool sweater
   7. gloves

Miscellaneous Box

HAZMAT Boxes (2)

		Quantity
1. Dike/sock	8" x 10'	4
2. Dry sorb granules (kitty litter)		6
3. Diapers (17"x19")		2
4. Mop Bucket (wringer type)		1
5. Spill Bucket (5 gallon)		2
6. Coverall (Tyvek)		6
7. Gloves (Nitrile)		12
8. Safety Goggles		6
9. Trash Bags		approx 40

NOTE: Gloves, Goggles and Trash bags are stored in Bucket

Photographic Support: Photographic documentation of the demonstration will be provided by NFESC technical personnel.

Data: Data will be taken by CNA representatives for all three systems during the conduct of the demonstration using the data sheets provided in appendix A.

Communications: Primary communication will be via Saber Radio with alternate via cell phone. CWO-4 Collins will issue Saber Radios and cell phones to key DMFDS Support Team personnel listed in paragraph 3 above and to van drivers. Once communication assets are issued CWO-4 Collins and Mr. Nixon will publish a cell phone directory to all DMFDS Support Team personnel.

Transportation: CWO-4 Collins will have two administrative vans with drivers (USMC SOFA Drivers) for utilization by the DMFDS Support Team. All requests for van support will be approved by CWO-4 Collins. CWO-4 Ray will have one a dministrative van with driver (USMC SOFA Driver) in support of the Joint/Combined JP-8 Fuel Exercise at the Pohang ROKMC Base. CWO-4 Ray van will be the back up van for the DMFDS Support Team as required by CWO-4 Collins.

Safety Plan & Hazard Analysis: 1.0 TEST DESCRIPTION. Refer test plan for an overview of the tests, including a description of the test objectives, site locations, and test personnel. The test Safety Officers will be assigned from NFESC, ACU5 and shipboard personnel for each test. The specific personnel have not been assigned.

Overall Safety. Overall safety for the DMFD test/demonstration falls under the responsibility of the concept demonstration leader,CWO-4 Collins.

a) Everyone involved in the tests is responsible to observe safe working practices and is authorized to stop the test should any unsafe condition arise during the test. The test will be stopped until the unsafe condition is resolved to the satisfaction of the concept demonstration leader.

Proper shipboard and lighter operational practices will be observed during the test.

Proper material handling techniques will be observed during the test.

At all times while MHE is moving equipment to/from/around the cargo areas, personnel will be advised.

- In the event of an mishap or accident resulting in personnel injury the accident response and subsequent treatment will be provided by and in accordance with established USN and USMC procedures depending upon the location of the accident. Following immediate treatment through miltary channels civilian personnel will have the option to seek additional treatment in accordance with their own medical plan or coverage.

Preliminary Hazard Analysis

Potential Hazards: In addition to hazards normally associated with shipboard/lighter operations, the following is a list of DMFD specific hazards/concerns:

Hazard to personnel while lifting: Components are heavy and may be required to be maneuvered into place by hand. Proper lifting techniques will be used to minimize lifting related injuries. In addition, a fork lift will be used whenever possible.

Hazard to personnel while securing bladders to LCAC: Securing items to the deck of the LCAC will require the use of wire ropes and tensioning devices. Care is required to avoid cuts and pinching. Proper gloves will be required during this activity. Open-ocean operations: Some tests will be conducted on board an LCAC operating off shore. As per standard LCAC operating procedures, no one will be allowed on the cargo deck during operation. When “off cushion” it is permissible to be on the deck, and it will be required during some portions of the test to check rigging, instrumentation, etc. Extreme care will be exorcised on these occasions.

Trip hazard: There is an increased trip hazard associated with the restraints of the 15k DMFD when restrained aboard the LCAC. Personnel are advised to be aware.

Crushing hazard: There is increased possibility of severe injury due to crushing while placing the 3k or 400 DMFD aboard the LCAC if personnel get caught between the cabin of the LCAC and the flatrack. Personnel are advised to stay clear of this load/unload operation.

Hand/Finger injury: There is possibility of sever injury to hands and fingers while assembling the 400 DMFD tanks. The lid weighs approx 150 pounds and has a ¼” thick lip which is inserted into the bottom of the tank. This interface provides considerable shear (guillotine) and could sever fingers. Personnel are cautioned to keep hands and fingers clear during this operation.

Pinch hazard: While sliding restraint support poles into the uprights of the 3k DMFD, there is possibility of pinching any flesh caught between the upright and the pole. Personnel are advised to be aware.

Skin irritant: The dye used to color the water, though safe is listed as a skin irritant. Personnel are advised to followsafety instructions on the attached MSDS (Appx F).

FOD hazard: Though considered the responsibility of the LCAC crew, deck cleanliness is everyone’s responsibility. Items left on the deck during the loading and restraining of DMFD systems can be drawn into the LCAC fans causing equipment damage or personal injury. All personnel involved in DMFD test/evaluation have a personal responsibility to insure the LCAC deck is clear of possible Foreign Object Damage (FOD) prior to leaving the deck.

Risk Assessment Code (RAC): A maximum RAC of 4 - Minor is assigned to these tests based on the Hazards Severity Code and Mishap Probability assigned, discussed below. These were selected based on an assessment of the test plans, associated hazards, and the experience and training of personnel involved in the tests.

Hazard Severity Code: The Hazard Severity Code corresponding to the worst potential consequence likely to occur as a result of deficiency during these tests is Category II - Critical, corresponding to severe injury or major property damage.

Mishap Probability: The Mishap Probability applicable to these tests is Sub-Category D - Unlikely to Occur.

Safety Measures and Hazard Control Mechanisms: All LCAC operations will be in accordance with the U.S. Navy’s standard operating procedures for LCAC. All tests pertaining to the LCAC will also be performed in the presence of the ACU-5 safety officer.

The safety officer has the authority and responsibility to unilaterally halt the tests if, for any reason, he determines that continuing would pose a risk to personnel safety or equipment.

PERSONAL PROTECTIVE EQUIPMENT.

Safety Shoes: Safety shoes are required for all personnel involved with any lifting and rigging operations to support the test. Individuals are responsible for providing their own safety shoes.

Hard Hats: Hard-hats are required for all personnel involved with any lifting and rigging operations to support the test. Individuals are responsible for providing their own safety hard hats.

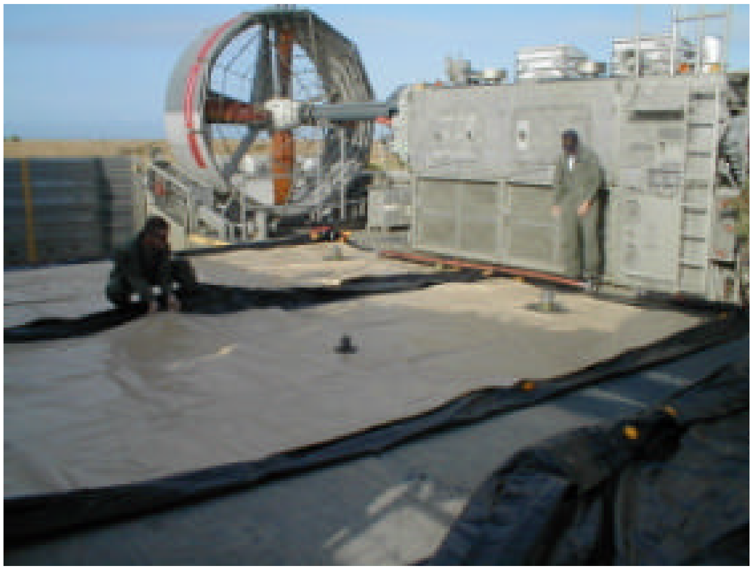
Safety Vests: All personnel involved in the on-water portions of this test will wear a buoyant safety vest at all times during the test. Safety vests will be provided by ACU-5.

Environmental Compliance: All personnel will follow Unit/Organizational SOPs for Spill Prevention Control and Countermeasures (SPCC) aboard ship, in transits and at the Dogu Beach tactical fuel site. NFESC has developed and published an approved DMFD environmental plan, which will be reviewed by all DMFD Support Team members before the commencement of fuel operations. ❖

DMFD Test/Evaluation

15-18 May 2000

DMFD TEST/EVALUATION



APPENDIX C

15K DMFD PRELIMINARY OBSERVATIONS:

1. The 15k DMFD system was installed on the LCAC deck by the LCAC crew. The crew consisted of anywhere from four to six individuals during the installation process. They were trained on the system the previous week.

NOTE: The craft master (top picture) was uncomfortable traversing the ramp with a full load, therefore the tanks were secured to the deck empty, then filled at the base of the ramp.

2. The crew took 37 minutes to install the system in preparation for filling. However, since the system would not be filled until the craft proceeded to the bottom of the ramp, the crew proceeded to secure the DMFD to the deck. This process took an additional 54 minutes. 10 minutes were lost to repositioning tie-downs that were installed in the wrong position. The installation manual will need to clarify location of tie-down points and methodology.

   NOTE: Two problems occurred during installation:

   a) One of the tanks was dragged a short distance (1 to 2 feet) over the non-skid surface to make way for installing the spill containment. This resulted in several holes in the bottom of the tank, the largest about the size of a dime. The tanksupplier patched the holes prior to continuing with the test. Unfortunately, the patch did not take and the tank leaked throughout the test.

   b) Several air tubes were over inflated in the spill containment, resulting in ruptures. These were left as is for the test.

3. Tanks were filled individually, enabling griping to be completed concurrently with filling of each subsequent tank. It took 72 minutes to complete filling of all tanks. This resulted in an average flowrate of 175 gpm. Time required to fill tanks is dependent on each ship's pumping capability. Therefore only the time required to complete griping after filling the last tank is needed. Since only the last tank needed to be secured, this took only 8 minutes. The height of the tanks when "full" was 35 inches.

4. The LCAC left the beach and proceeded to deep water to simulate roughest seas possible. The craft master estimated the seas were a little higher than sea-state 1, but not quite a sea-state two, with a 5-foot swell. The craft heading was directly into the swells at approximately 35 knots. The craft appeared to experience close to zero gravity several times, and one occurrence of upward force notably greater than 1 G. The load was checked after the run and no problems with tanks or tie-downs were detected. After the flight, the craft master stated the load to be "stable" and "better than some rolling stock loads".

   NOTE: Because of the craft's fuel load, it was decided to simulate the weight of fuel rather than full volume of the tanks. This resulted in a load weight of approximately 105,000 lbs from 12,600 gallons of water. This is approximately 85 percent of the tank's design capacity. There was notable wave propagation within each tank during the flight test, but this did not result in noticeable control problems for the LCAC crew.

5. The LCAC landed on white beach at a 90 degree angle to the surf and with the bow ramp pointing directly at the receiving "fuel" tanks set up on the beach. From the time the bow ramp was lowered, the Marines took less than 5 minutes to assemble their suction hose (four 25-foot lengths) and connect the suction hose to the 15k outlet.

6. The 15k DMFD was discharged to a 20,000-gallon flexible tank using a 600-gpm pump. Though we would recommend one at a time, the Marines

preferred to empty all simultaneously. Discharge took 28 minutes. This equates to an average flowrate of 450 gpm.

7. The Marines reversed the pump and refilled the DMFD using the 600-gpm pump to simulate filling from a second source. All four tanks were filled simultaneously to a total of 15,000 gallons, taking 25 minutes. This equates to an average flowrate of 600 gpm. Height gages were used to indicate when the tanks were full, while a flow totalizerwas used for confirmation.

8. Again, the tanks were discharged simultaneously with the 600-gpm pump. Time to discharge was 33 minutes, equating to a discharge flowrate of 455 gpm.

9. The empty tanks were secured to the deck and air emptied from the spill containment in preparation for return. This took 15 minutes. Again, if tanks are emptied one at a time, the crew can secure one tank while emptying the next. This can reduce the time to less than 5 minutes.

10. The LCAC then departed the beach for a short sortie to demonstrate how the system reacts when empty. After about 5 minutes the LCAC returned to ACU5. When operating in reverse pitch, blast from the drive propellers tends to "pick up" the aft two tanks slightly. This causes some "pooching" of the tanks that requires they be stretched out before filling again.

11. Time to remove system from the deck was not recorded.

12. There was no visible damage to the system other than those previously noted.

13. Comments/Suggestions include:
    a) The spill containment proved useful in containing the leak in one of the tanks.
    b) Either equip each air tube on spill containment with relief valves or change to a system that does not require inflating.
    c) Add abrasion patches under the fittings on the tanks to increase abrasion resistance.
    d) Separate the four tanks into two sets of two, with independent manifolds. This will enable the Bulk Fuel Company on the beach to utilize two pumps to discharge the system in half the time.

14. Observations:
    a) Anticipated time to install and prepare the system is 45 minutes in addition to the time it would take to fill the tanks. Therefore, if the ship is capable of filling a 200 gpm (75 minutes) then total time would be 120 minutes (2 hrs). Likewise, if the ship were only capable to 100 gpm, then the total time would be 195 minutes (3 hrs, 15 min).
    b) Anticipated LCAC loitering time on the beach would be 45 minutes if one 600-gpm discharge-pump is utilized, or 25 minutes if configured for two pumps.
    c) It is always recommended that the tanks be filled to capacity. The tanks were only filled to 85 percent of capacity to simulate fuel weight for this demonstation. This resulted in considerable wave propagation within each tank. Though this had no detrimental affect to craft handling or the tanks themselves, it should be avoided whenever possible. If carrying capacity of the craft is limited due to weather or equipment problems, it is recommended that the DMFD configuration be changed such that fewer tanks are installed and placement is adjusted for optimal craft center of gravity.

3,000 DMFD

1. After one day of training, setting up a single system once, a crew of 4 Marines was able to set up two (2) complete systems in 75 min. The assembly instructions provided in the test plan were followed as a rough guide as system simplicity allowed intuitive installation once the general idea was understood.

2. Loading onto the LVS took approximately 8 minutes.

3. The only problems identified with the system assembly were:
    a. the paint on the tank restraint support poles caused binding when sliding through the uprights
    b. need a better method of connecting the ends of the top and bottom tank restraint halves
    c. uprights are built to slide into the stake pockets of the 1077 flatrack. If the stake pockets are damaged (bent), it is impossible to insert the uprights
    d. the manifold restraints slid into the rear stake pockets were too tight

e. it is imperative that the tanks be centered fore/aft in the bottom restraint half prior to filing the system

4. Fill was accomplished from an available fire hydrant. Air was purged from the manifold by breaking the connection where the manifold enters the tank and opening the valve until water appeared at the outlet of the manifold. Fill was completed in 11 minutes for the first system (1600 gal), 10 minutes for the second system (1780 gal). Flow rate during the majority of the filling was in the order of 260 gpm, flow was reduced as the system neared full to prevent overfilling/bursting of the tank.

5. Problems identified with the system fill were:
   a. the manifold is way too complicated with too many potential leaks (connections)
   b. there is no suitable means for purging air from the manifold when working with fuel
   c. the 4" camlock on the manifold is not a drybreak connection even though backed by a valve on the manifold
   d. the PT Coupling dry break connections between the manifold and the tanks weren't dry break but in fact leaked
   e. the hose length on the manifold to tank connection appeared to be short causing the tank outlet to be pulled once the tanks were full

6. Loading the filled system onto the LVS proved to be a simple task for the equipment and operator, however the LVS operator needs to be aware/ reminded to keep the load angle as shallow as possible. When set in the "auto" mode, the LVS will raise the flatrack at an unacceptably steep angle causing unnecessary strain on the tank restraint systems.

7. When loading the system onto the LVS, it became apparent that the tank restraints weren't sufficiently tight to adequately restrain the system in the fore/ aft direction. In one case, the tanks actually slid to the rear when raised to the angle required to load onto the LVS.

8. The systems were positioned on the LCAC one starboard, one port between the tiedown holes on the craft. Both systems were placed behind the thwart ship centerline to balance the 400 DMFD which was placed forward. Dunnage was placed under the flatrack rollers to distribute the load across a larger portion of the LCAC deck. Lumber (2x10x12' long boards) was placed longitudinally for the rollers to roll on, the thwart ship under the ISO corner castings on the front of the flatrack.

9. The first system was positioned and offloaded in 13.5 minutes, the second system was offloaded in 11.25 minutes. Total time to load both systems was 34 minutes.

10. The systems were griped using standard LCAC 35,000 pound gripes. Two (2) gripes were used from the flatrack bail bar down (3 holes forward) to the gripe rails on the deck. Two (2) additional gripes were put from the flatrack lift ring forward (6 holes) and crossed to the gripe rail. The rear of the system was secured with two (2) gripes from the flatrack lift rings aft (6 holes) and crossed to the gripe rails. Exact time to gripe was not taken as three (3) systems were being griped simultaneously by the LCAC crew. Time to gripe all three (3) systems was 38 minutes.

11. The system was carried aboard the LCAC through the surf into the open ocean for 28 minutes over a distance of approximately 20 miles (per LCAC pilot). Average speed during the transit was approximately 40 knots. The sea state during the transit was high SS1 breaking into SS2. During the transit, zero gravity was experienced (lifted out of the seat) approximately 5 times, there were some white caps (approx 2%) visible, light breeze with approximately 30% cloud cover heavier to the east. There were no problems associated with the transit. Discussion with the pilot after the transit revealed a "stable

load, rigid ride".

12. The LCAC landed on the beach and parked at about 45° facing out.

13. It took the LCAC crew 7 minutes to remove the gripes from all three (3) systems once the ramp was down at the beach.

14. Offload at the beach is not straight forward. The LVS uses a Front Lift Adapter (FLA) to move the flatracks. The FLA connects to both the bail bar and the front corner castings of the flatrack. The FLA remains with the LVS and is reconnected to the flatrack each time the flatrack is retrieved. Attaching the FLA in anything other than ideal (smooth, level ground) is a challenge. Removing the flatracks from the LCAC required reattaching the FLA which added time to the evolution. Time to offload the systems was 10 -15 minutes each.

15. The LVS drove off the LCAC ramp directly onto soft sand and proceeded to get stuck requiring the TRAM to give it a push to dislodge it. While stuck, the LVS "pumped" and bounced in an attempt to generate some forward momentum. During this bouncing, the tanks could be seen completely leaving the deck of the flatrack due to slack in the top restraint half. Upon inspection, it was found that the tanks had shifted forward and were hard against the front of the flatrack.

16. To remove any unnecessary stress on the tanks, the manifolds were removed from the system during the drive around. The manifolds caused the tank outlet to pull towards the center due to the short connection hose and relative motion between the manifold and the tanks when the tanks shifted position due to the slack restraints.

17. The drive around was accomplished over various terrain. Starting on the beach for approximately .6 miles, followed by 6 miles on paved road at 20 miles/hour, 7 miles off road at a typical cargo hauling speed (per operator), 6 miles on paved road and .6 miles on the beach (20 miles total). During the off road portion, it was apparent that the tank restraints were in fact loose as the tanks rolled from side to side on the sloping terrain.

18. The approximate load on the LVS was eight (8) tons. LVS operators indicated that the load was stable and proved to be no problem to load or transport.

19. The systems were pumped out using the MC 600 gpm pump. One hundred fifty (150) feet of 4" suction hose was connected from the pump inlet to the system manifold. Flowrate from the first system was approximately 90 gpm, while flowrate from the second system was in the order of 180 gpm. The nature of the manifold and the center connection on the tank required someone to hold the tank connection into the fluid once the tank got about 2/3 empty.

20. Once pumped out, the systems were returned to the LCAC apron area where they were disassembled and packaged for return to NFESC. Residual water was drained from the tanks by rolling and lifting the tanks in a similar fashion to the way collapsible fire hose is drained.

21. There was no visible damage to the system upon disassembly.

22. Comments heard about the system and improvements suggested are as follows:
    a. the manifold is way too complicated, with too many potential leak areas (threaded connections)
    b. the manifold could be simplified considerably by merely running two hoses off a 4" wye
    c. the tanks need to have a D-1 pressure locking connection for fill/drain
    d. the tanks need openings on each end to facilitate recirculation
    e. the tank outlet should be off center to facilitate draining of the tank without requiring it to be lifted, or requiring someone to push the tank fitting into the fluid
    f. a flanged bolt ring on the tank outlet would allow the installation of a standard 4" D-1 connection directly to the tank
    g. "its so light"

400 DMFD

1. Evaluation of the 400 DMFD began with the pallet manifold already mounted to the 1077 flat rack.. Eight (8) tanks were previously removed from the pallet/manifold (2 tanks remained on the manifold because the retaining pins couldn't be removed due to interference with the flatrack) and broken down in their "storage" configuration.

2. Tank assembly began with three (3) Marines assembling tanks, as more personnel were available, up to six (6) Marines ended up assembling tanks. Time to assemble all eight (8) tanks was 25 minutes. There was some confusion with crossing the tank liner "suspenders" which required two (2) tanks to be disassembled and reassembled which added to this overall time.

3. Tank installation onto the pallet/manifold was done sequentially with tank assembly rather than simultaneously as it could have been. Tank installation took 45 minutes using a 15k commercial forklift. Installation was slow in proceeding due to some tight retaining pins being encountered requiring a hammer to entice them into position. The "tight pins" added about 10 minutes to the installation process.

4. Tank connection, like installation was accomplished sequentially rather than

simultaneously. Tank hose connections took about 10 minutes to accomplish on all 10 tanks.

5. The system was loaded aboard the LVS in approximately 5 minutes.

6. The system was filled at a fire hydrant through a 2 ½ firehose and meter. Air was first bled from the manifold by breaking one of the forward tank connections and allow air to escape until water was noticed at the connection.Flowrate for the fill was measured at 400 gpm with a total volume of 3426 going into the ten (10) tanks. The auto shutoff operated without a problem even at this high flowrate.

7. The full system was loaded back onto the LVS in about three (3) minutes.

8. The system was loaded onto the LCAC in 10 minutes. As with the 3,000 DMFD, the system was set down onto dunnage to distribute the load across a greater area on the LCAC deck. Lumber (2x10x12' long boards) was placed longitudinally for the rollers to roll on, the thwart ship under the ISO corner castings on the front of the flatrack. The 400 DMFD was placed on the longitudinal centerline between gripe rails, and forward of the thwart ship centerline to balance the load of the two (2) 3,000 DMFD placed behind the centerline.

9. The system was griped using standard LCAC 35,000 pound gripes. Two (2) gripes were used from the flatrack bail bar down (3 holes forward) to the gripe rails on the deck. Two (2) additional gripes were put from the flatrack lift ring forward (6 holes) and crossed to the gripe rail. The rear of the system was secured with two (2) gripes from the flatrack lift rings aft (6 holes) and crossed to the gripe rails. Two (2) additional gripes were used on each side from the pallet/manifold lift rings to the far gripe rail to provide additional lateral stability. Exact time to gripe was not taken as three (3) systems were being griped simultaneously by the LCAC crew. Time to gripe all three (3) systems was 38 minutes.

10. The system was carried aboard the LCAC through the surf into the open ocean for 28 minutes over a distance of approximately 20 miles (per LCAC pilot). Average speed during the transit was approximately 40 knots. The sea state during the transit was high SS1 breaking into SS2. During the transit, zero gravity was experienced (lifted out of the seat) approximately 5 times, there were some white caps (approx 2%) visible, light breeze with approximately 30% cloud cover heavier to the east. There were no problems associated with the transit. Discussion with the pilot after the transit revealed a "stable load, rigid ride".

11. The LCAC landed on the beach and parked at about 45° facing out.

12. Offload at the beach is not straight forward. The 400 DMFD weighed an estimated twenty (20) tons with all 10 tanks full of water which overloads the LVS in off-road mode. Additionally, the 400 DMFD was placed forward on the LCAC deck to balance the overall craft load which then required the LVS to park on the ramp to retrieve the 400 DMFD. The LVS operator was hesitant to try and lift the much weight in that somewhat precarious position and requested that the load be lightened. This was accomplished by gravity draining the system onto the deck ofthe LCAC.

13. The LVS uses a Front Lift Adapter (FLA) to move the flatracks. The FLA connects to both the bail bar and the front corner castings of the flatrack. The FLA remains with the LVS and is reconnected to the flatrack each time the flatrack is retrieved. Attaching the FLA in anything other than ideal (smooth, level ground) is a challenge. Removing the 400 DMFD from the LCAC required reattaching the FLA which added time and complexity to the evolution due to the LVS operating on the ramp . Time to connect the FLA was about 25 minutes. Time to completely offlaod the systems was 35 minutes.

14. The LVS drove off the LCAC ramp directly onto soft sand and proceeded to the LCAC apron without incident. where it was disassembled and packaged for return to NFESC. Residual water was drained from the individual tanks by removing the tank top and lifting on the tank liner to allow residual to drain onto the ground. During this process, it was noted that there was a uniform and consistent level of water (est 2 cups) found between the tank shell and the liner. As the amount of water between the shell and liner was consistent, this is assumed to be condensation.

15. There was no visible damage to the system upon disassembly.

16. Once completely drained, the tanks were reassembled in their shipping configuration and installed on the pallet/

manifold ready for transport.

17. Comments heard about the system and improvements suggested are as follows:
    a. There is a concern about the center of gravity of the system aboard the LVS, the "improved pallet" with integral bail bar will reduce this CG by 12" by eliminating the need for the flatrack.
    b. LCAC crew suggested some sort of vertical attachment be incorporated into the rear corner castings to facilitate vertical restraint on the rear of the unit.
    c. The tank "belly band" currently is tightened via a threaded connection, it is suggested that this be replaced by an over center cam device to facilitate assembly.
    d. In the storage mode, "What happens if the tanks are outside and it rains? Will the top fill with water and be too heavy to lift?"
    e. As designed, the tanks currently cannot be moved by TRAM because the fork pockets are too close.
    f. The retaining pins are too tight, possibly increase the diameter of the holes in the pallet/manifold to make it easier to insert the pins.
    g. The rear tank to pallet restraint mechanism isn't intuitive to the forklift operator.
    h. The hose restraining chain on the tank inlet isn't sufficient to stand up to field use.
    i. The current filter/separator is only two(2) stage, MC requirements are for three (3) stage filtration (monitor).
    j. Current filter/separator uses commercial API filter elements, MC standard is to use Mil-Spec elements.
    k. The tank liners appear to be flimsy, maybe a more durable liner with fabric reinforcement to make it more field friendly.
    l. As it is currently designed, it is near impossible to replace a tank liner in the field. Need some sort of access to the liner attachment bolts to facilitate field replacement of liner.
    m. Need bot an air eliminator and D-1 connection on the manifold.
    n. The unisex x camlock adapter needs to include a unisex x female camlock as well. This can be accomplished by merely adding a female x female camlock adapter to the existing adapter. ❖

APPENDIX D

Marine Forces Pacific Force Warfighting Lab
Expeditionary Bulk Liquids Focus Team

CHARTER

1. Purpose and Scope. The MARFORPAC Force Warfighting Lab (FWL) Expeditionary Bulk Liquids Focus Team (EBLFT) is comprised of bulk petroleum and water operational, technical, scientific and engineering experts from MARFORPAC, I MEF, III MEF and the Naval scientific community. The purpose of this charter is to establish the focus team's mission and membership.

2. Mission.

    a. The mission of the focus team is to assist the Commander MARFORPAC in determining operational and tactical bulk liquids (petroleum and potable water) MAGTF requirements and the most reliable and efficient procedures to support those requirements under current and future doctrine. In particular, the focus will center on the following aspects of MAGTF Bulk Liquids operations:

        (1) Operational Maneuver From The Sea (OMFTS)

        (2) Ship To Objective Maneuver (STOM)

        (3) Traditional Amphibious Assault ship to shore (Ship to CSSA) distribution

        (4) MAGTF ashore bulk liquids distribution

        (5) MAGTF expeditionary water purification

    b. The focus team will utilize the following venues to identify, document and field test concepts and equipment:

        (1) Submission of Fleet Operational Needs Statements (FONS) and review of Mission Needs Statements (MNS), Required Operational Capability (ROC), Operational Requirements Documents (ORD) to assist MCCDC in defining the scope for bulk liquids doctrine and material changes and solutions.

        (2) Coordinate with Office of Naval Research (ONR), MARCORSYSCOM, MCCDC, I MEF, III MEF, CPF, 3rd Fleet and 7th Fleet to field-test prototype bulk liquids equipment and emerging doctrinal concepts at MARFORPAC and CINC exercises.

        (3) Through ONR and MARCORSYSCOM, establish information sharing relationships with private sector bulk liquids technology experts to become aware of emerging technologies.

        (4) Establish informational sharing relationships with MARCORSYSCOM, MCCDC and the U.S. Army's Tank, automotive and Armaments Command (TACOM) to identify emerging warfighter requirements and provide input into doctrine and acquisition initiatives.

3. Membership and Responsibilities.

    a. MARFORPAC Science and Technology Advisor (STA). MARFORPAC STA will:

        (1) Provide emerging scientific and engineering information to the focus team.

        (2) Coordinate with ONR and other such agencies on emerging technologies that would be of interest to the focus team.

        (3) Act as advisor to the focus team.

        (4) Ensure resources and support as required are available for efficient operation of the focus team.

        (5) Provide status updates to the MARFORPAC Force Warfighting Lab Executive Steering Committee (ESC), Working Group (WG) and other interested parties concerning the focus teams initiatives.

b. MARFORPAC Bulk Liquids Officer. The MARFORPAC Bulk Liquids Officer will:

(1) Chair the focus team.

(2) Coordinate with the MARFORPAC Science Advisor and the MEF focus team members concerning team initiatives and information sharing among members.

(3) Coordinate with MARFORPAC staff sections for field testing and evaluation of bulk liquids concepts and prototype equipment at exercises and demonstrations.

(4) Coordinate with MCCDC, MARCORSYSCOM and TACOM concerning focus team involvement in emerging bulk liquids equipment and doctrine requirements.

(5) Prepare briefs and other documents to the MARFORPAC Force Warfighting Lab and other interested parties concerning the focus team initiatives.

c. MEF Members: The MEF focus team members will:

(1) Coordinate with their MSC bulk liquids experts and operating forces concerning current and future equipment and doctrine issues for consideration by the focus team.

(2) Coordinate focus team initiatives approved by MARFORPAC for field testing in their respective AORs.

(3) Assist in analyzing, documenting and reviewing focus team initiatives and FONS, MNS, ROC and ORD documents.

(4) Encourage and educate their MSC technical experts in the importance and proper submission of FONS to identify current and future bulk liquids material and doctrinal issues.

d. Scientific Community Technical Members: The technical focus team members will:

(1) Provide information on emerging technologies and technical initiatives that may be of importance to the focus team for consideration and potential concept demonstration.

(2) Provide on-site command and control and technical analysis of any FWL sponsored experimentation.

(3) Provide information and briefs on technical initiatives that have been partnered with the Force Warfighting Lab for consideration or demonstration.

(4) Assist the Force Warfighting Lab in establishing and promoting communication networking with DOD and private enterprises dealing with emerging bulk liquids technology and requirements.

4. Focus Team Members:

CWO-4 Dave Ray	MFP Bulk Liquids Officer	MFP Representative, Chair
CWO-4 Mike Giambruno	MWSS 372	I MEF Representative
CWO-4 Robert Collins	3rd FSSG	III MEF Representative
Mr. Claude “Buck” Thomas	NFESC	Technical Representative
Mr. Mark Miller	NFESC	Technical Representative

5. Charter Updates: This charter will be updated on an annual basis.

6. Charter Approval:

Shujie Chang, STA, MFP
Established by WG Chair

MajGen Robert Magnus, Deputy Cmdr, MFP
Approved by ESC Chair

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